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USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET--ETC(U)
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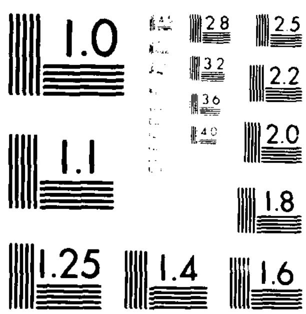

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INSTRUCTION REPORT K-81-2

USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET PILE WALLS BY CLASSICAL METHODS (CSHTWAL)

Report 1

COMPUTATION PROCESSES

by

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February 1981

Report 1 of a Series

A report under the Computer-Aided Structural *Engineering* (CASE) Project

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under Contract No. DACW39-79-M-1229

Monitored by Automatic Data Processing Center
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO ATTENTION OF:

DAEN-CWE-DS

23 February 1981

SUBJECT: Instruction Report K-81-2, User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL), Report 1 and Report 2

All Corps Elements with Civil Works Responsibilities

1. The subject user's guide documents a computer program named CSHTWAL that can be used for analyzing and designing cantilever and singly anchored sheet pile walls. The program specification for CSHTWAL was developed by the Computer-Aided Structural Engineering (CASE) Task Group for Pile Structures and Substructures. As is the goal with all CASE tasks, the intent is to make an organized, cost-effective computer solution available to the Corps' designers for use when the need arises.

2. Engineers will be readily able to tell by the description of the program and by the examples given in the report of the applicability toward their needs. Detailed documentation of the program may be obtained from the Engineering Computer Programs Library (ECPL) of the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS.

3. We strongly encourage the use of these programs where applicable throughout the Corps.

FOR THE CHIEF OF ENGINEERS:

Lloyd A Duscha

LLOYD A. DUSCHA
Chief, Engineering Division
Directorate of Civil Works

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Instruction Report K-81-2	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET PILE WALLS BY CLASSICAL METHODS (CSHTWAL). Report 1. Computational Processes	5. TYPE OF REPORT & PERIOD COVERED: Report 1 of a series
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): William P. Dawkins	8. CONTRACT OR GRANT NUMBER(s): Contract No. DACW39-79-M-1229
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Oklahoma State University, Department of Civil Engineering, Stillwater, Okla. 74074	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Office, Chief of Engineers, U. S. Army, Washington, D. C. 20314	12. REPORT DATE: February 1981
	13. NUMBER OF PAGES: 203
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): U. S. Army Engineer Waterways Experiment Station, Automatic Data Processing Center, P. O. Box 631, Vicksburg, Miss. 39180	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This report was prepared under the Computer-Aided Structural Engineering (CASE) Project. A list of published CASE reports is printed on the inside of the back cover.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer-Aided Structural Engineering Project
Computer programs
CSHTWAL (Computer program)
Retaining walls
Safety factor
Sheet piles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a computer program called "CSHTWAL" for design and analysis of either anchored or cantilever sheet pile retaining walls. The program is written for interactive use from a remote terminal.

Stratified soil profiles, irregular ground surfaces, arbitrary water levels, and a variety of vertical and horizontal external loads are permitted in the description of the wall-soil system. Net pressures on the wall are determined either by Coulomb coefficients or by a wedge method. Effective soil internal friction angle and effective soil cohesion are used for (continued)

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20. ABSTRACT (Continued)

development of pressures.

The program determines the required penetration for a given factor of safety, or, in the analysis mode, the factor of safety is determined for a given penetration. The conventional procedure for calculation of design penetration is used for cantilever walls. Five alternative procedures (free earth, fixed earth, equivalent beam, equal moment, and Terzaghi) are available for investigation of anchored walls.

Output from the program consists of a summary of results containing design penetration or factor of safety with maximum bending moment, maximum relative deflection, and anchor force. A complete tabulation of net soil pressures, bending moments, shears, and deflections is available at the user's option.

Example solutions and supporting verification of results are provided to demonstrate the use of the program.

PREFACE

This user's guide documents a computer program called "CSHTWAL" that can be used for the design and analysis of sheet pile walls using classical methods. The work in writing the computer program and the user's guide was accomplished with funds provided to the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., by the Civil Works Directorate of the Office, Chief of Engineers, U. S. Army (OCE), under the Computer-Aided Structural Engineering (CASE) Project.

Specifications for the program were provided by members of the CASE Task Group on Sheet Pile Structures. The following were members of the Task Group (though all may not have served for the entire period) during the period of development of the program:

Mr. Terry Soupos, North Central Division (Chairman)
Mr. Richard Albert, Detroit District
Mr. James Bigham, New Orleans District
Mr. Walter Green, Nashville District
Mr. Tom McGee, Nashville District
Mr. Louis Mendell, New York District
Mr. T. Samuelson, Seattle District
Mr. Ken Waddell, Huntington District

During the latter stages of development of the program and this user's guide, the Sheet Pile Structures Task Group was combined with the Pile Foundations Task Group and renamed the Pile Structures and Sub-Structures Task Group. This new Task Group then assumed responsibility for the program. The Pile Structures and Sub-Structures Task Group is composed of the following members:

Mr. Tom Mudd, St. Louis District (Chairman)
Mr. James Bigham, New Orleans District
Mr. Roger Brown, South Atlantic Division
Mr. Dick Chun, Pacific Ocean Division
Mr. Walter Green, Nashville District
Mr. Joe Hartmann, St. Louis District
Mr. Roger Hoell, St. Louis District
Mr. Phil Napalitano, New Orleans District
Mr. Arthur Shak, Pacific Ocean Division
Mr. Ralph Strom, Portland District

The computer program and user's guide were written by Dr. William P. Dawkins, P.E., Professor of Civil Engineering, Oklahoma State

University, under Contract No. DACW39-79-M-1229 with WES.

This report only addresses the computational processes of CSHTWAL. Report 2 of this series will be published at a later date to present the interactive graphics capabilities which will be built into the program.

Dr. N. Radhakrishnan, Special Technical Assistant, Automatic Data Processing (ADP) Center, WES, and CASE Project Manager, coordinated and monitored the work. Mr. H. Wayne Jones, Computer-Aided Design Group (CADG), ADP Center, WES, supported the Task Group in compiling program specifications. He and Ms. Dorothy B. May, CADG, helped in converting the program to the WES, Boeing, and Macon computers. Messrs. Donald M. Dressler and Rixby Hardy, Civil Works Directorate, were OCE points of contact. Mr. Donald L. Neumann was Chief of the ADP Center, WES, during the development of the program and the preparation of this user's guide.

Directors of WES during this period were COL J. L. Cannon, CE, and COL N. P. Conover, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONTENTS

CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
pound (force)-feet	1.355818	newton-metres
pound (force)-inches	0.1129848	newton-metres
pounds (force)	4.448222	newtons
pounds (force) per square foot	47.88026	kilopascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per foot	1.488164	kilograms per metre

USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET PILE WALLS BY CLASSICAL METHODS (CSHTWAL)

COMPUTATIONAL PROCESSES

PART I: INTRODUCTION

General

1. This report describes a computer program called CSHTWAL which performs design and/or analysis of either cantilever or anchored sheet pile walls. CSHTWAL is designated X0031 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) library.* The program uses classical soil mechanics procedures for determining the required depth of penetration of a new wall or assesses the factor of safety for an existing wall. Seepage effects are included in a simplified manner in the program. CSHTWAL was developed from specifications provided by the Computer-Aided Structural Engineering (CASE) Task Group on Sheet Pile Structures. The program follows as a minimum the procedures outlined in draft Engineer Manual 1110-2-2906, "Design of Pile Structures and Foundations," dated 16 November 1970.

Organization of Report

2. The remainder of this report is organized as follows:

   a. Part II describes the general sheet pile retaining structure and soil system to be designed or analyzed by the program.

   b. Part III describes the procedures employed in the program for calculating earth pressures on the wall due to adjacent

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* Three sheets entitled "PROGRAM INFORMATION" have been hand-inserted inside the front cover of this report. They present general information on the program and describe how it can be accessed. If procedures used to access this and other CORPS library programs should change, recipients of this report will be furnished a revised version of the "PROGRAM INFORMATION."

soil, due to unbalanced hydrostatic head, and due to surcharge loads on the soil surface.

c. Part IV reviews the methods used in determining the required depth of penetration for each type of wall.

d. Part V describes the computer program.

e. Part VI presents example solutions obtained with the program.

3. The program has been checked within reasonable limits to assure that the results obtained by it are accurate within the limitations of the procedures employed. However, there may exist unusual situations which were not anticipated which may cause the program to produce questionable results. It is the responsibility of the user to judge the validity of the final design of the system, and no responsibility is assumed for the design of any structure based on the results of this program.

PART II: GENERAL WALL/SOIL SYSTEM

General

4. The same basic wall/soil system shown in Figure 1 is used for either anchored or cantilever sheet pile walls. Throughout development of the program is was assumed that all effects of the wall were tending to cause counterclockwise rotation of a cantilever wall and clockwise rotation of an anchored wall. This section presents other assumed characteristics for the various components of the general system.

Sheet Pile Wall

5. A 1-ft* slice of a straight, uniform wall is used for the design/analysis process. The wall is assumed to be straight, initially vertical, linearly elastic, and to have a constant cross section throughout its depth.

Anchor

6. For anchored walls, a single horizontal anchor may be attached to the wall at any elevation at or below the top of the wall. The anchor is assumed to prevent horizontal displacement of the point of attachment.

Soil

7. In subsequent paragraphs, reference is made to the "right" side and "left" side of the wall. The soil surface on either side must intersect the wall at or below the top of the wall.

Soil Surface

8. The irregular soil surfaces illustrated in Figure 1 provide for all variations of soil surface geometry including horizontal or continuous sloping (either up or down away from the wall). The slope of any segment of a broken surface may not exceed the effective internal friction angle of the surface soil.

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* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page 5.

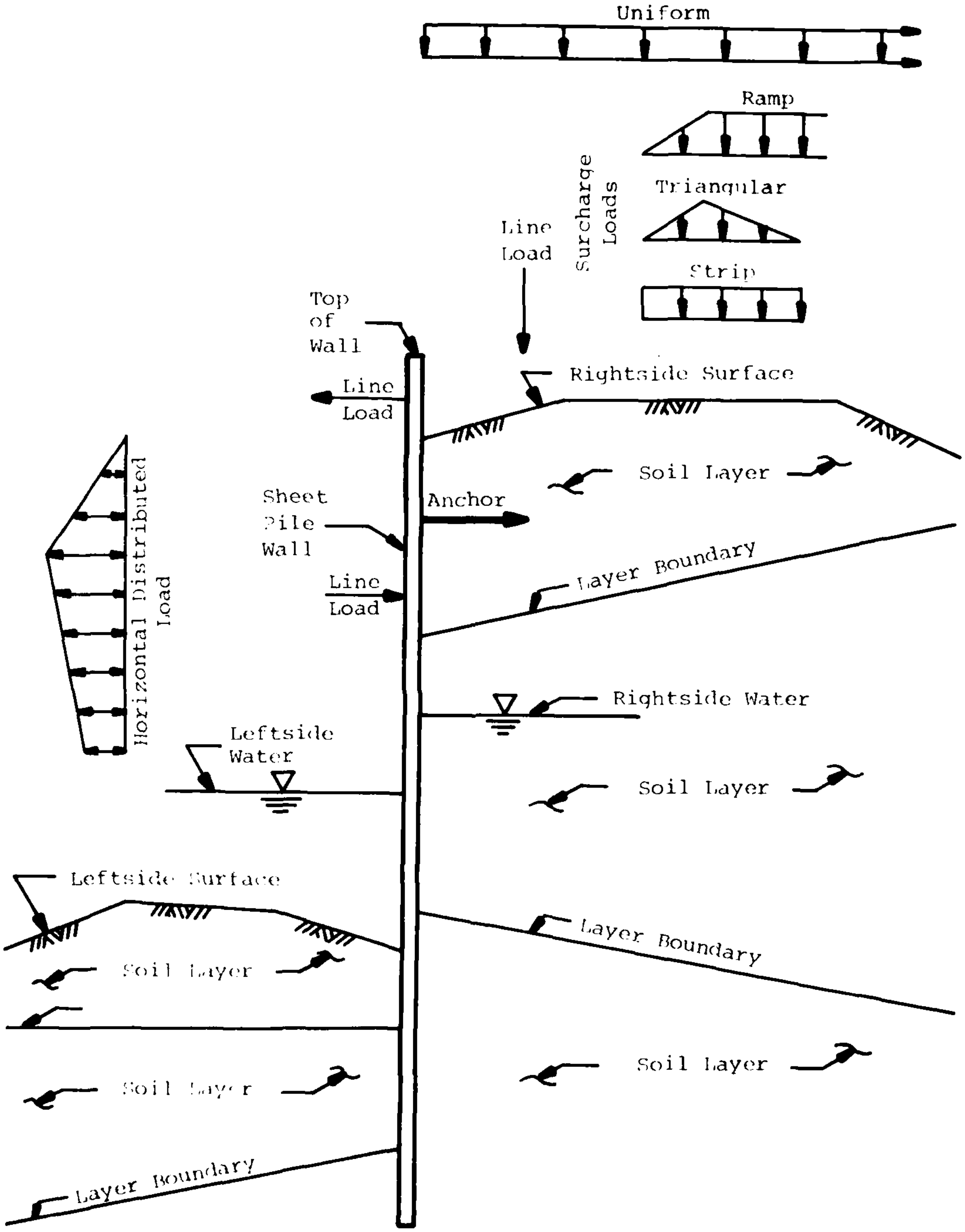


Figure 1. General wall/soil system

Soil Profile

9. A different layered soil profile is assumed to exist on either side of the wall. Boundaries between subsurface layers are assumed to be straight lines sloping up or down away from the wall on either side. Sloping boundaries must diverge away from the wall or be parallel. Layers are assumed to extend ad infinitum away from the wall and the lowest layer described on either side is assumed to extend ad infinitum downward.

Soil Properties

10. Each soil layer is assumed to be homogeneous. Properties required for each layer are

a. Soil unit weight--γ: The program determines the buoyant unit weight for submerged soil according to

$$\gamma' = \gamma - \gamma_{we}$$

where γ' = buoyant unit weight; and

γ_{we} = effective unit weight of water (see Paragraph 32, Part III).

Hence, the unit weight provided as input is assumed to be the saturated unit weight for submerged soil. Soil above the water surface in other than a saturated condition must be described as a separate soil layer.

b. Actual angle of internal friction--ϕ: The program determines the effective angle of internal friction according to

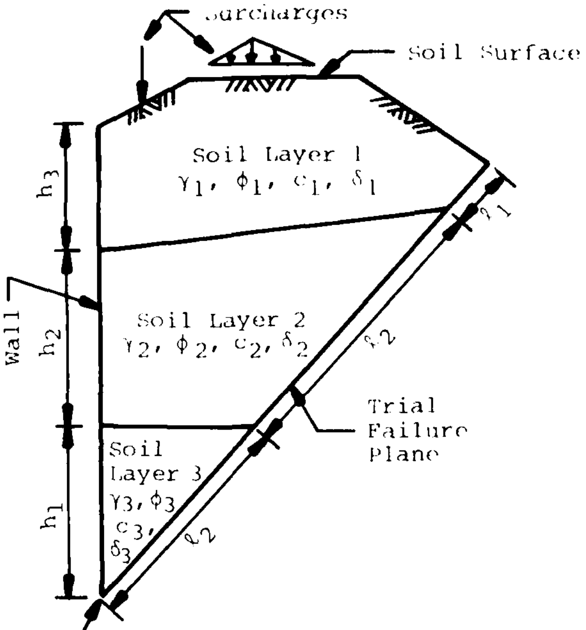
$$\phi_{eff} = \mathrm{Tan}^{-1}[(\mathrm{Tan}\phi)/FS]$$

where FS = given or calculated factor of safety.

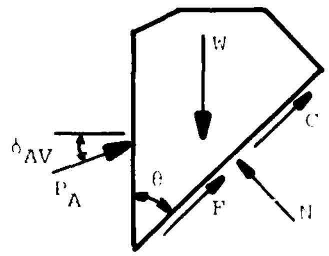
c. Actual cohesion--c: The program determines the effective cohesion from

$$c_{eff} = c/FS.$$

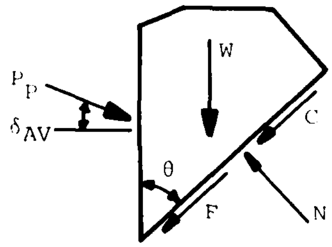
d. Effective angle of wall friction--δ: The program does not alter the angle of wall friction. See Figure 2 for assumed positive wall friction angle.



(a) Failure Wedge



(b) Free Body Diagram for Active Soil Force



(c) Free Body Diagram for Passive Soil Force

W = weight of wedge for effective soil unit weight including surcharge loads

N = normal force on failure plane

F = friction force on failure plane

$F = N \cdot \tan \phi_{AV}$ where $\phi_{AV} = (\Sigma\phi_i \ell_i)/\Sigma\ell_i$

C = cohesion force on failure plane

$C = \Sigma c_i \ell_i$

δ_{AV} = average wall friction angle

$\delta_{AV} = (\Sigma\delta_i h_i)/\Sigma h_i$

Figure 2. Forces for calculation of soil pressure by wedge method

Water

11. The following effects due to water are considered:

   a. Static water. Horizontal pressures due to hydrostatic head are applied on either side of the wall. Static water surfaces may be at any elevation. When the water surface is above the top of the wall, a drop structure is assumed, and only the trapezoidal pressure distribution below the top of the wall is used.

   b. Seepage effects. Seepage effects alter static water pressures and the submerged weight of the soil. The approximations used to account for seepage are discussed in Paragraph 32. When seepage is present, the water surface on the right side must be above that on the left side.

   c. Earthquake effects. Earthquake effects alter hydrostatic pressures only on the right side above the ground surface (see Paragraph 19).

Vertical Surcharge Loads

12. Surcharge loads are assumed to exist only on the right side surface. Five types of surcharge loads are permitted as illustrated in Figure 1.

Vertical Line Loads

13. Vertical line loads are assumed to extend horizontally parallel to the axis of the wall and to act on the soil surface. The program accommodates four (4) line loads at any location on the right side surface.

Distributed Loads

14. Four distributed load variations are permitted by the program as shown in Figure 1. Only one distributed load is permitted in the design/analysis of a particular wall description. All four distributions

are assumed to extend horizontally parallel to the wall. Distributed loads may only be applied to a horizontal segment of the rightside surface. A break in the rightside surface within the limits of a distribution is not permitted. A uniform surcharge is assumed to extend ad infinitum away from the wall and may be applied only to a horizontal surface.

Horizontal Loads

15. Two types of external horizontal loads in addition to other soil and water loads may be applied to the wall. Horizontal loads acting to the left are positive.

Horizontal Line Loads

16. The program permits up to four (4) line loads (positive or negative) to be applied directly to the wall at any location at or below the top of the wall.

Horizontal Distributed Loads

17. A single general horizontal load distribution described by elevations and load values for a maximum of twelve (12) points may be applied to the wall. Changes in sign (direction) within a distribution are not permitted.

Earthquake Effects

18. Earthquake effects are assumed to increase the tendency toward rotation of the wall. Earthquake effects on soil pressures are simulated in the program by altering the soil unit weight on each side of the wall as follows.

Rightside: $\gamma_{eff} = \gamma(1 + \alpha) - \gamma_{we}$

Leftside: $\gamma_{eff} = \gamma(1 - \alpha) - \gamma_{we}$

where α = earthquake acceleration expressed as a fraction of the acceleration of gravity.

19. Earthquake effects on water pressures above the rightside soil surface are included by application of an additional pressure distribution extending from the rightside water surface to the rightside soil according to

$$P_y = C_e \, \alpha\sqrt{hy}$$

where

$C_e = 51/\sqrt{1 - 0.72 \, (h/1000)^2}$;

h = distance from rightside water surface to rightside soil surface; and

y = distance below rightside water surface.

PART III: LOADS ON WALL

General

20. Horizontal loads are imposed on the structure by the surrounding soil, by surcharge loads on the right side surface, by water pressures or by horizontal loads applied directly to the wall. The following paragraphs describe the procedures used in the program for determining the resultant horizontal pressure distributions.

Calculation Points

21. Locations at which force magnitudes and wall response are calculated are initially located at the following points:

- a. At one-foot intervals staring at the top of the sheet pile.
- b. At the intersections of the surface and/or layer boundaries on either side with the wall axis.
- c. At the point of application of each horizontal line load and at each elevation point of a distribution.
- d. At the location of the water surface on either side of the wall.
- e. At the anchor elevation for anchored walls.
- f. At other locations to establish the resultant force or pressure distribution as necessary for each design procedure.

Soil Pressures

22. Two methods of classical soil mechanics are used in the program to establish the design pressure distributions. Inherent in each method is the assumption that the wall displaces sufficiently to produce a fully plastic state in the soil on either side of the wall. This assumption results in full values of active and passive earth pressure at every point regardless of actual displacement.

Pressure Coefficient Method

23. Coulomb earth pressure coefficients relating horizontal pressure to vertical pressure are used for the following combinations of wall/soil characteristics:

a. Right Side Surface

a(1) Continuous sloping or horizontal surface without surcharge loads.

a(2) Continuous horizontal surface with surcharge loads.

b. Left Side Surface--continuous sloping or horizontal.

c. Soil Layers--horizontal layer boundaries for subsurface layers on both sides of wall.

Pressures by Coefficient Method

24. Soil pressures are calculated as follows:

a. The vertical pressure, p_v, at each point is calculated using the effective soil-unit weight (including submergence and/or earthquake effects) for the soil above that point and any uniform surcharge.

b. The Coulomb earth pressure coefficients are

b(1) Active pressure coefficient

$$K_A = \left[\frac{\cos \phi_{eff}}{1 + \sqrt{\frac{\sin(\phi_{eff} + \delta)}{\cos \delta}\frac{\sin(\phi_{eff} - \beta)}{\cos \beta}}}\right]^2 \cdot \frac{1}{\cos \delta}$$

b(2) Passive pressure coefficient

$$K_p = \left[\frac{\cos \phi_{eff}}{1 - \sqrt{\frac{\sin(\phi_{eff} + \delta)}{\cos \delta}\frac{\sin(\phi_{eff} + \beta)}{\cos \beta}}}\right]^2 \cdot \frac{1}{\cos \delta}$$

where ϕ_{eff} = effective angle of internal friction;

δ = angle of wall friction (may be positive or negative); and

β = angle of surface slope (positive upward away from wall, determined by program).

c. Horizontal earth pressures are calculated from:

c(1) Active pressures

$$p_{Ah} = K_A\, p_v - 2c_{eff}\sqrt{K_A}$$

c(2) Passive pressures

$$p_{Ph} = K_P\, p_v + 2c_{eff}\sqrt{K_P}$$

d. When a change in either ϕ_{eff} or c_{eff} occurs at a layer boundary, dual pressure values are calculated using the soil properties above and below the boundary.

Wedge Method

25. For all cases involving irregular soil surfaces on either side of the wall, surcharges on a sloping rightside surface and/or nonhorizontal subsurface layer boundaries, the wedge method described below is used.

26. A failure plane is assumed to emanate from each calculation point described in paragraph 21. The wedge established by the failure plane and the methods for calculating the various forces on the wedge are shown in Figure 2.

27. The angle of inclination θ, Figure 2b and 2c, of the failure plane with the wall is increased in one degree increments until the maximum active force and the minimum passive force for that calculation point are determined. In some systems having downward sloping surfaces, maximum active and minimum passive forces may not be achieved before the trial failure surface no longer intersects the soil surface. When this situation is encountered, a warning is printed and the active and/or passive force associated with the last failure plane interesecting the soil surface is used at that point.

28. Final soil pressures are calculated under the assumption that the difference between active and passive forces for two adjacent calculation points is the resultant of a linear pressure distribution between the two points.

Net Soil Pressures

29. Four separate soil pressure distributions are determined by the methods described above.

a. Active pressure for the rightside soil.

b. Passive pressure for the rightside soil.

c. Active pressure for the leftside soil.

d. Passive pressure for the leftside soil.

All calculated negative active pressures are set to zero.

Pressures Due to Surcharge Loads

30. The effects of surcharge loads on the rightside surface are included in the weight of the failure wedge and no additional computations for surcharge loads are required when soil pressures are determined by the wedge method.

31. When the coefficient method is used to determine soil pressures, the additional horizontal pressures on the wall due to strip, ramp, and triangular surcharge loads are calculated from the theory of elasticity equations shown in Figure 3. A uniform surcharge is added directly to the vertical soil pressure as indicated in paragraph 24.

Water Pressures

32. In addition to earthquake effects (Paragraph 19), hydrostatic pressures may be altered by seepage. When seepage effects are included, the excess hydrostatic head is assumed to be dissipated by vertical flow downward on the right side and upward on the left side. The flow gradient $\underline{i}$ (FT/FT) is assumed to be constant at all points in the soil on either side. Under this assumption, the effect of seepage is to alter the effective unit weight of water in the region of flow to

Right side: $\gamma_{we} = \gamma_w (1 - i)$

Left side: $\gamma_{we} = \gamma_w (1 + i)$

The effect of seepage on net horizontal water pressures is illustrated in Figure 4. (Note: When the program is operating in the "Design" mode, the point at which net horizontal pressure reduces to zero for an

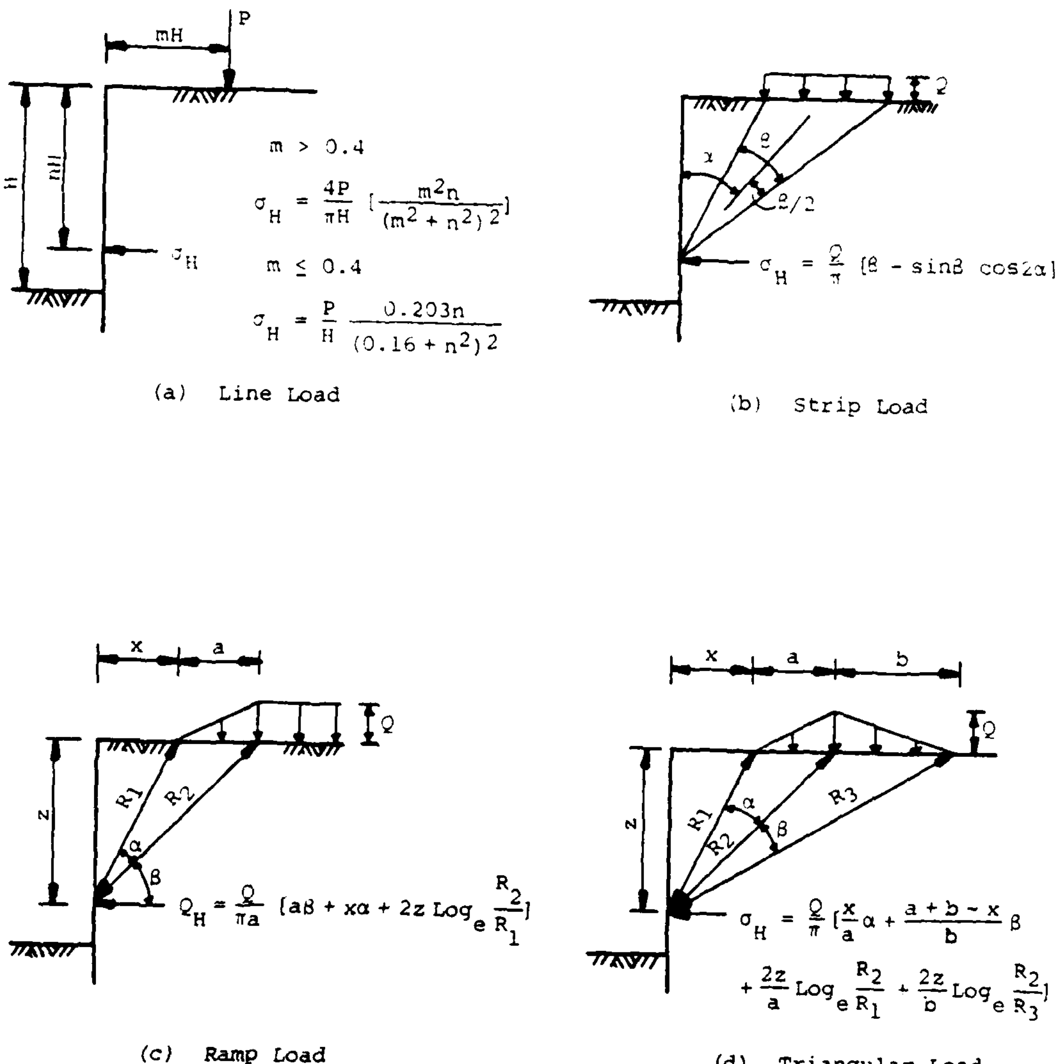
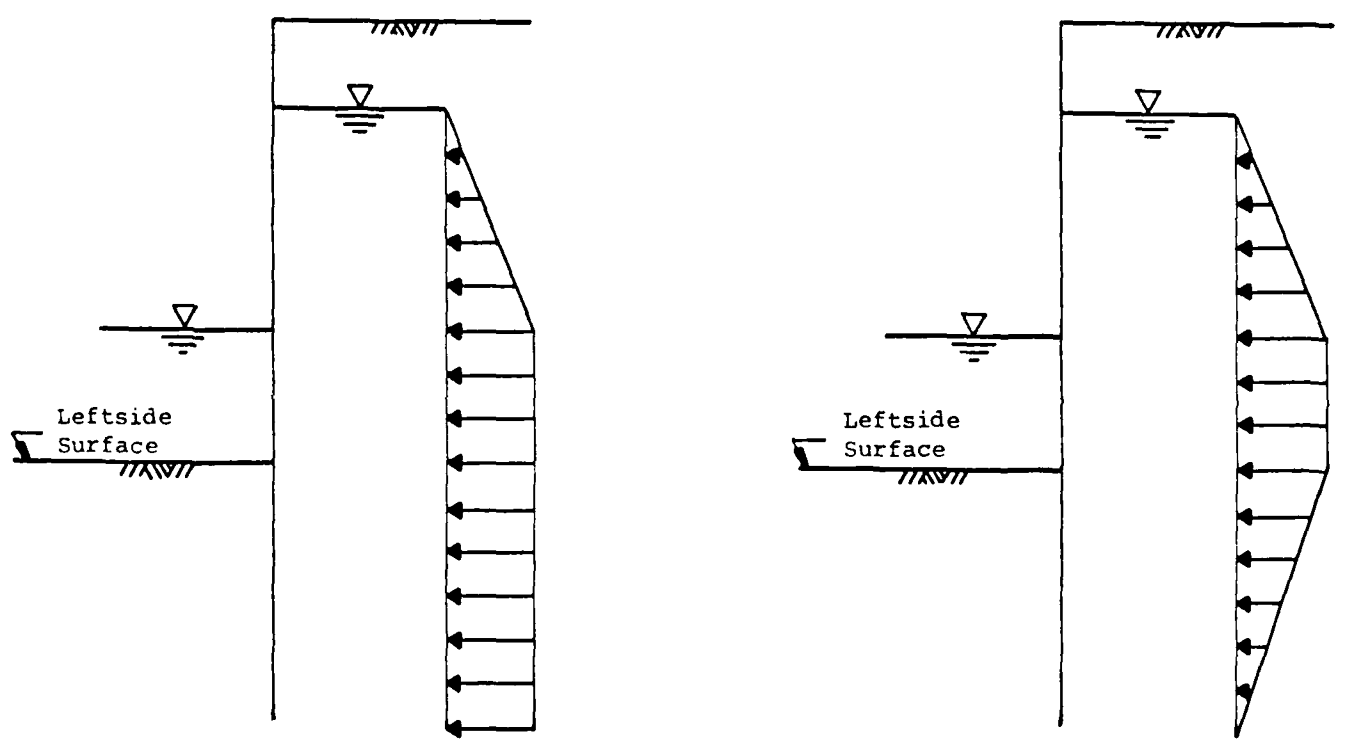


Figure 3. Theory of elasticity equations for pressures on wall due to surcharge loads



(a) Net Water Pressure Without Seepage

(b) Net Water Pressure With Seepage

Figure 4. Pressure distributions for unbalanced hydrostatic head

input seepage gradient may not coincide with the design bottom of the wall.)

Design Pressures

33. The following combinations of all applicable loading effects are used for the final design.

Net Active Pressure = Rightside Soil Active Pressure - Leftside Soil Passive Pressure + Surcharge Pressure + Water Pressure + Distributed External Horizontal Pressure.

Net Passive Pressure = Rightside Soil Passive Pressure - Leftside Soil Active Pressure + Surcharge Pressure + Distributed External Horizontal Pressure + Water Pressure.

Horizontal Loads

34. Horizontal line and distributed loads are applied directly to the wall. Depending on their sense (positive to the left) and point of application, horizontal loads may have either a stabilizing or disturbing effect on the wall.

PART IV: DESIGN/ANALYSIS PROCEDURES

General

35. The program provides two modes of operation. In the "Design" mode, the required depth of wall penetration is determined for input soil strengths, geometry, loading, and factor of safety. Iterative solutions are performed in which wall penetration is varied until conditions of equilibrium and other assumptions are satisfied. In the "Analysis" mode, the safety factor for input strengths, geometry, loading, and prescribed penetration is determined. In the analysis mode, a succession of design calculations are performed in which the factor of safety is adjusted until consistent factor of safety and effective soil strength properties yield a design penetration equal to the input value. In unusual layered systems, in which the wedge method is used for soil pressures, it is possible for minuscule changes in the factor of safety to produce a large change in required penetration, indicating a discontinuity in the relationship between factor of safety and penetration. When this condition is encountered, a solution for a unique factor of safety is impossible and the process is terminated.

36. In either the "Design" or "Analysis" mode, a structural analysis is performed to determine bending moments and shears in the wall at the locations of the calculation points. Relative deflections (i.e., the deflected shape of the wall) are calculated for both modes of operation. However, the pile moment of inertia is not known a priori in a design situation, hence the deflections of the wall in the "Design" mode are determined for wall modulus of elasticity and moment of inertia both equal to one. Because the wall is assumed to be a linear system for structural analysis, the "scaled" deflections reported from the "Design" mode may be converted to actual relative deflections by dividing by the product of modulus of elasticity and wall moment of inertia after these parameters have been selected by the designer.

37. The design methods utilized in the program are described in detail in References 1 through 4. The salient features of each method are summarized below.

Cantilever Wall Design

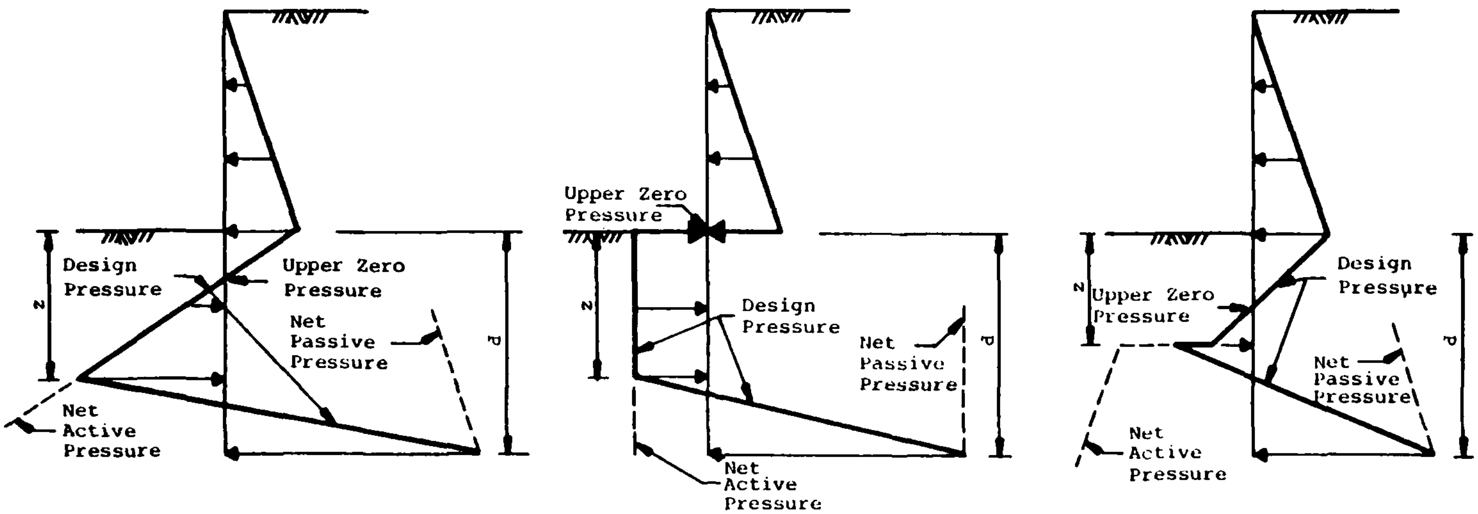
38. The assumptions employed in the conventional design procedure are:

- a. The wall rotates counterclockwise as a rigid body about a point somewhere in its embedded depth.
- b. Due to the rotation full active and passive earth pressures are developed on either side of the wall.
- c. The wall derives its support from passive pressures on either side of the wall.

39. Typical simplified pressure distributions arising from the above assumptions are shown in Figure 5. A final design is achieved when values of penetration d and depth z of the transition point produce a pressure distribution for which the sum of moments about the bottom of the wall and sum of horizontal forces are simultaneously equal to zero.

40. The process used in the program to determine the required penetration is as follows. Starting at the first calculation point below the upper zero pressure point (Figure 5a and b), the bottom of the wall (i.e., penetration d) is moved progressively downward until values of d and z are found which produce a horizontal resultant force equal to zero. The resultant moment is then calculated. When a reversal in resultant moment is found, the depth of penetration is adjusted between the last two calculation points until the resultant moment is less than a prescribed minimum tolerance.

41. The incremental procedure described above converges without difficulty to a design penetration for all cases in which the design pressures discussed in paragraph 33 increase monotonically with depth. However, soil pressures calculated by the coefficient method for stratified subsoils may have discontinuities in the net active pressure distribution such as shown in Figure 5c. If the pressure at the transition point z is restricted to either of the extreme values at a discontinuity, a solution may not be possible. For these cases a solution is obtained by the program by allowing the pressure at the transition point to assume values intermediate to the extremes in order to obtain zero resultants.



(a) Homogeneous Granular Subsoil

(b) Homogeneous Cohesive Subsoil

(c) Special Case for Stratified Subsoil

Figure 5. Design pressure distributions for cantilever walls

Structural Analysis of Cantilever Walls

42. Following the "Design" for required penetration or "Analysis" for factor of safety, the bending moments, shears, and relative (or scaled) deflections are calculated under the assumption that the wall is a cantilever beam supported at the wall bottom and subjected to the final net pressures and other external loads.

Anchored Wall Design

43. Five conventional procedures are incorporated in the program for "Design" or "Analysis" of anchored walls. The user has the option of using any or all of the methods and it is the responsibility of the user to judge the applicability of the method employed. The program does not make this determination.

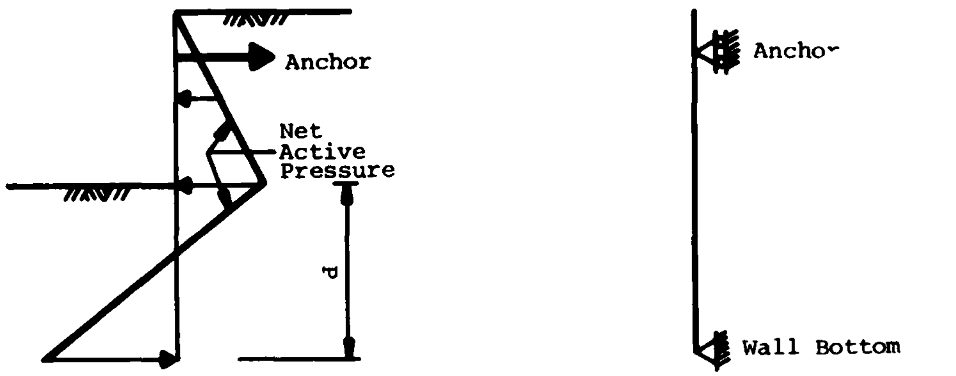
44. In the conventional procedure it is assumed that the motion of the wall will be sufficient to produce full active and passive pressures at every point. In all methods for anchored wall design the wall is subjected to the effects of the net active pressures due to soil, water, and surcharges described in paragraph 33. Other assumptions attendant to each method are discussed below.

Free Earth Method

45. In the Free Earth Method the design penetration d, Figure 6, is established by lowering the bottom of the wall until the sum of moments about the anchor of all forces is equal to zero. The anchor force is then equal to the equilibrant of all horizontal forces.

Structural Analysis for Free Earth Method

46. Bending moments, shears, and deflections are calculated by treating the wall as a beam with simple (unyielding) supports at the anchor and at the wall bottom, Figure 6b. The assumed bottom support has no influence on the bending moments and shears and only affects the relative (scaled) deflection values.



(a) Design Pressure

(b) Supports for Structural Analysis

Figure 6. Anchored wall design by free earth method

Fixed Earth Method

47. For the fixed earth method it is assumed that the penetration is sufficient to produce a transition from net active pressure on the left side to net passive pressure on the right side near the wall bottom similar to those shown for cantilever walls in Figure 5 and in Figure 7a. For a trial penetration the depth of the transition point z is adjusted until the moment about the anchor of the pressure diagram is zero. The wall is then analyzed as a beam on simple supports at the anchor and at the lower point of zero net pressure, as shown in Figure 7b. The design penetration is achieved when the tangent to the wall at the wall bottom is vertical. Because the net pressure diagram has zero moment about the anchor, there is no reaction at the lower simple beam support and the anchor force is equal to the horizontal resultant of the net pressure.

48. No additional structural analysis for this case is necessary, since bending moments, shears, and deflections are calculated during the determination of design penetration.

Equivalent Beam Method

49. The fundamental assumption for the Equivalent Beam Method is that the wall is embedded to a depth which produces a point of inflection in the deflected shape at some point below the leftside surface. The program assumes the point of inflection occurs at the first point of zero net active pressure at or below the leftside surface, Figure 8. For design, the portion of the wall above the point of zero pressure, Figure 8c, is treated as a beam on simple supports located at the anchor and at the point of zero pressure. The upper simple beam reaction is equal to the anchor force. The design penetration (i.e., distance y, Figure 8c) is determined by lowering the bottom of the wall until the net active soil pressure below the zero pressure point and the lower simple beam reaction R (Figure 8c) produce a zero resultant moment about the wall bottom. (Refer to Draft EM 1110-2-2906 for additional information on the Equivalent Beam Method.)

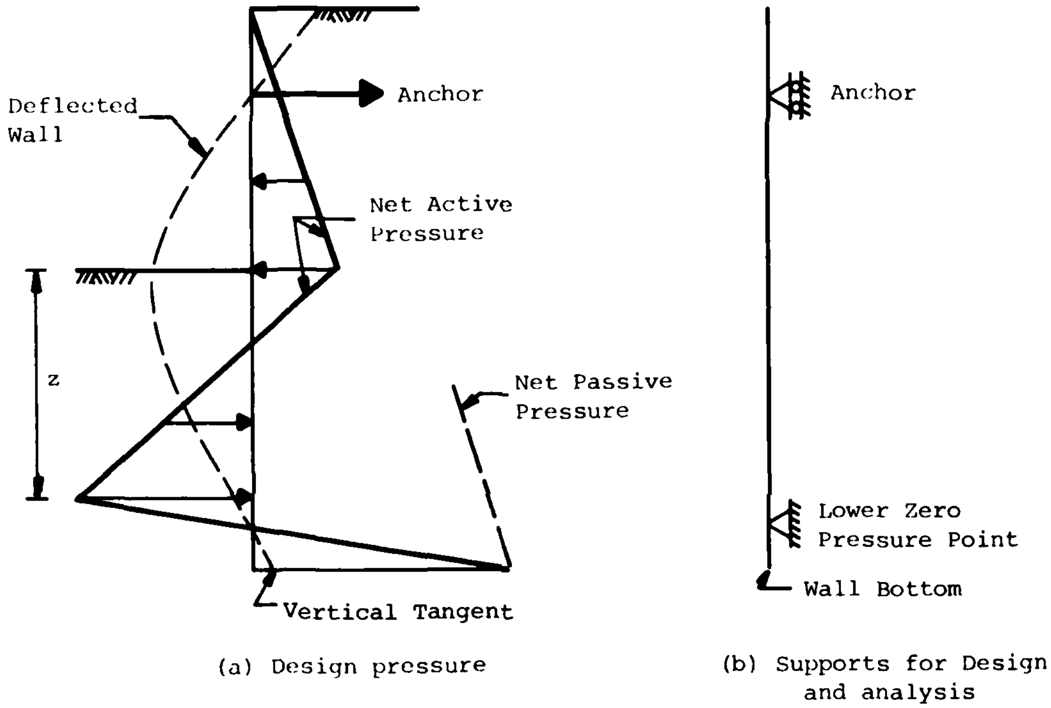
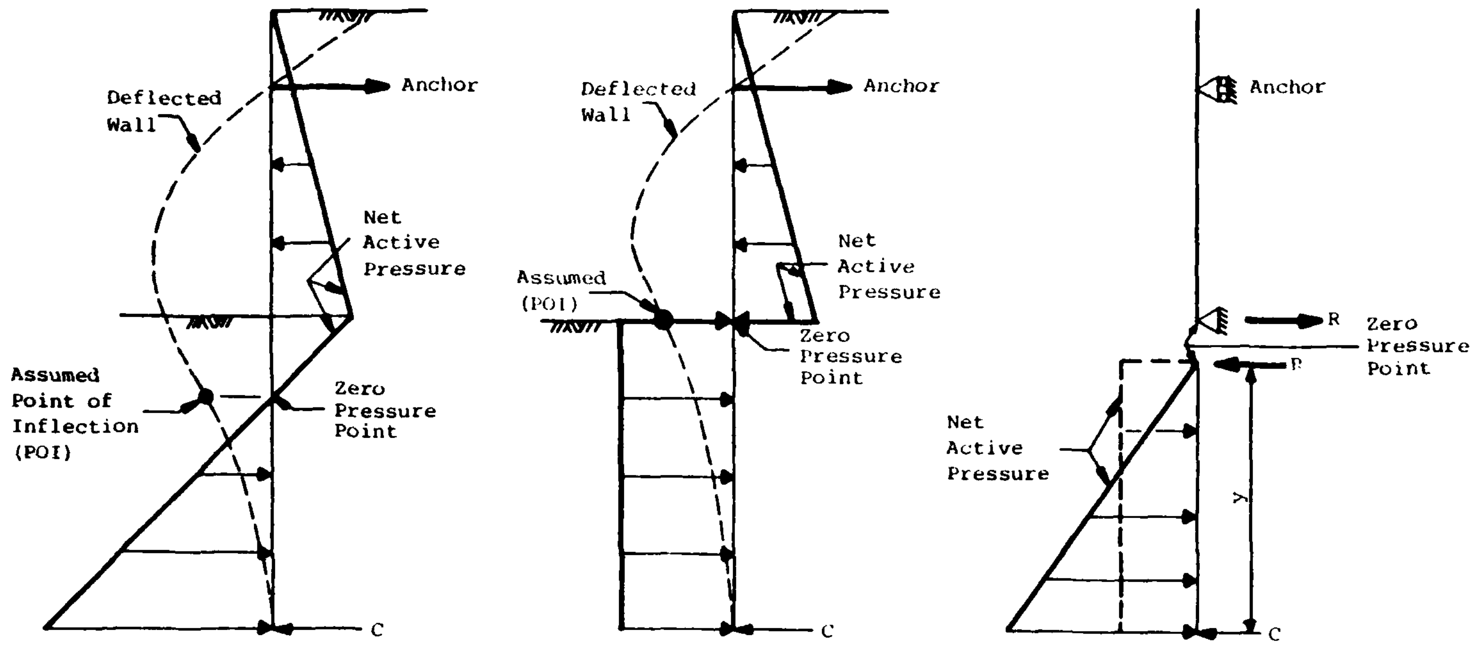


Figure 7. Anchored wall design by fixed earth method



(a) Granular Subsoil (b) Cohesive Subsoil (c) Equivalent Beam

Figure 8. Anchored wall design by equivalent beam method

Structural Analysis for Equivalent Beam Method

50. Bending moments, shears, and deflections are determined from a simple beam analysis of the portion of the wall above the zero pressure point with a deflection of zero at the lower support.

Equal Moment Method

51. The design penetration for the Equal Moment Method is established when the maximum negative bending moment below the leftside surface is equal to the maximum positive moment above the leftside surface, Figure 9. In the program the design penetration is determined by a simple beam analysis of the wall with supports at the anchor and at the wall bottom. The wall bottom is lowered until the maximum positive and negative moments differ by less than a prescribed minimum tolerance. Because the moments, shears, and deflections are calculated during determination of design penetration, no additional structural analysis is necessary for this method.

Terzaghi Method

52. The Terzaghi Method is a simplification of the Fixed Earth Method. In this procedure the portion of the pressure diagram below the transition point is replaced by a single concentrated force C, as shown in Figure 10a. The wall is subjected to net active pressure and is analyzed as a beam on simple supports at the anchor and at the wall bottom, Figure 10b. Design penetration is determined when the tangent to the deflected wall at the bottom is vertical.

53. No additional structural analysis for this method is necessary since bending moments, shears, and deflections are calculated during determination of design penetration.

Structural Analysis Procedure

54. A one-dimensional finite element procedure for linear, prismatic beams is used to perform the structural analysis of each type of wall. The nodes of the finite element model, Figure 11, are located at

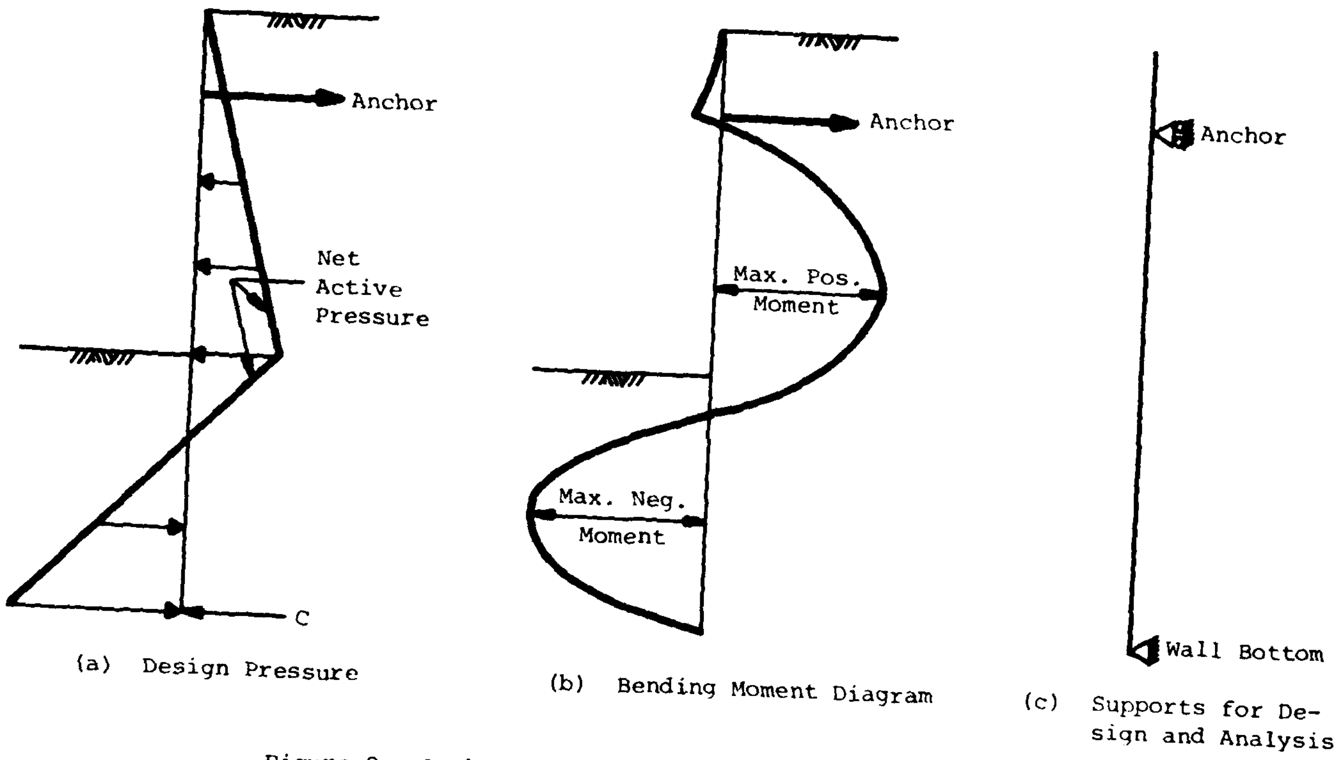
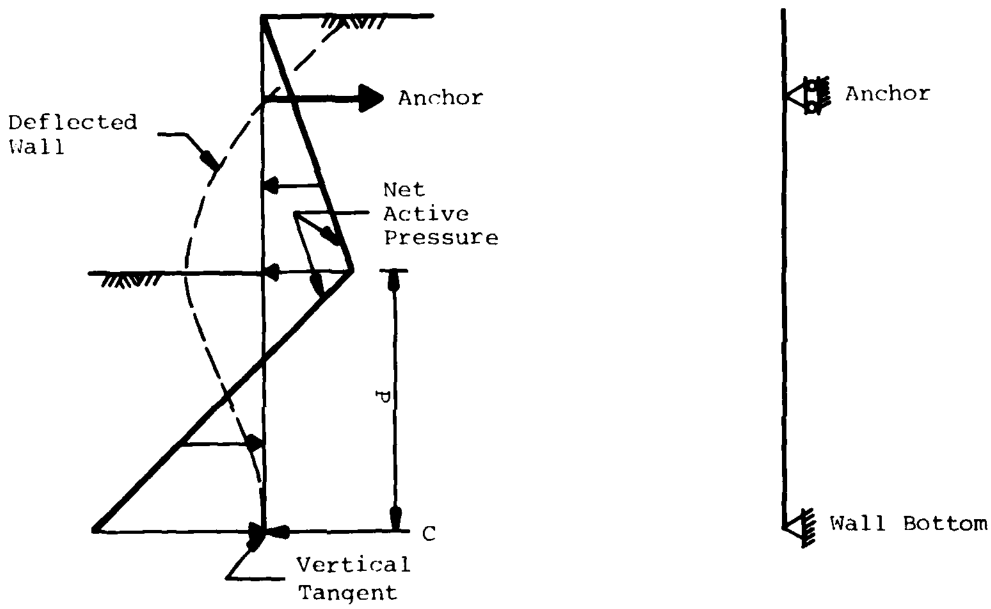


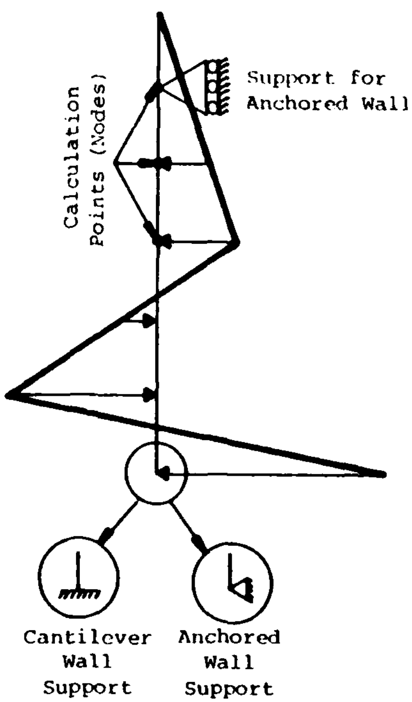
Figure 9. Anchored wall design by equal moment method



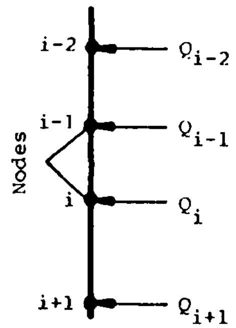
(a) Design Pressure

(b) Supports for Design and Analysis

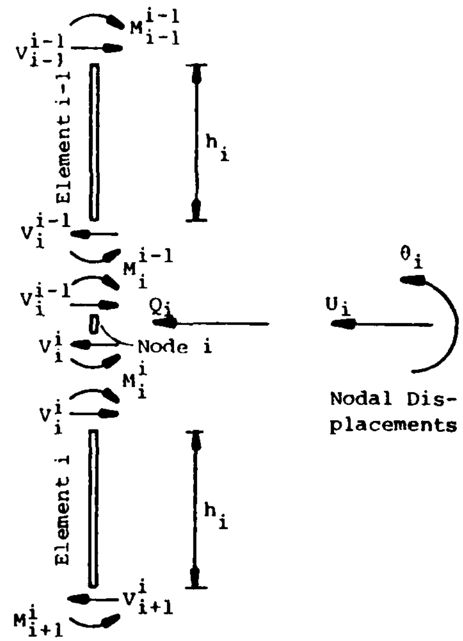
Figure 10. Anchored wall design by Terzaghi method



(a) Wall and Design Pressure



(b) Equivalent Concentrated Forces



(c) Typical Elements and Node

$$\begin{Bmatrix} V_i^i \\ M_i^i \\ V_i^{i+1} \\ M_i^{i+1} \end{Bmatrix} = \frac{EI}{h_i^3} \begin{bmatrix} -12 & 12 & 12 & 6h_i \\ 6h_i & -4h_i^2 & -6h_i & -2h_i^2 \\ -12 & 6h_i & 12 & 6h_i \\ -6h_i & 2h_i^2 & 6h_i & 4h_i^2 \end{bmatrix} \begin{Bmatrix} U_i \\ \theta_i \\ U_{i+1} \\ \theta_{i+1} \end{Bmatrix}$$

(d) Element Force-Displacement Relationship

$$\begin{Bmatrix} V_i^{i-1} \\ -M_i^{i-1} \end{Bmatrix} + \begin{Bmatrix} -V_i^i \\ M_i^i \end{Bmatrix} = \begin{Bmatrix} Q_i \\ 0 \end{Bmatrix}$$

(e) Nodal Equilibrium Equation

Figure 11. Finite element model for structural analysis

the calculation points described previously. Each node in the model has two associated displacements: a horizontal translation u, and a rotation θ. The distributed net design pressures, Figure 11a, are first converted to a system of equivalent concentrated nodal forces to produce the situation shown in Figure 11b.

55. Typical elements and their common node are shown in Figure 11c. The relationship between bending moments and shears on the ends of an element and the displacements of the nodes at the element ends, Figure 11d, is readily established using conventional beam bending theories.

56. Substitution of the element force-displacement relationship into the nodal equilibrium equations, Figure 11e, results in a pair of equations which must be satisfied at each node. When the equations for every node have been evaluated, the resulting simultaneous equations (2n equations for a model with n nodes) are solved for the nodal displacements. Back substitution of the nodal displacements into the element force-displacement relationships leads to the bendin moments and shears in the wall.

57. The bending rigidity parameter EI is assigned a value of one for all structural analyses. The displacements thus determined are referred to as "scaled" values. In the "Analysis" mode the scaled displacements are divided by the input values of E (modulus of elasticity) and I (wall moment of inertia) before the final results are reported.

PART V: COMPUTER PROGRAM

General

58. The computer program, SHTWAL, which implements the procedures described above is written in the FORTRAN language for interactive operations from a remote terminal. All arithmetic operations are performed in single precision. For computer systems employing fewer than fifteen significant figures for real numbers, it may be necessary to perform some operations in double precision. A complete listing of the FORTRAN source is provided in Volume 2 of this report and summary flow diagrams are provided in Figures 12, 13, and 14.

Program Description

59. The program is composed of 33 subroutines. The basic functions performed by each subroutine are described below.

60. MAIN: Through interactive questions and user responses:

- a. Determines mode for input data, either from user input at terminal or from previously prepared data file.
- b. Determines destination of output data, either to user terminal or to data files.
- c. Determines type of output desired, including echoprint of input data, summary of significant results, and/or complete tabulation of all results.
- d. Attaches user supplied input and output file names to I/O devices.

61. DESEX: Determines method to be used for calculation of soil pressures (coefficient or wedge method). Calls calculation routines for "Design" or "Analysis" of wall.

62. FSITER: Controls iterative sequence of calculations for determining factor of safety for a wall in "Analysis" mode.

63. ANCH: Determines required penetration for Free Earth, Equivalent Beam, Equal Moment, and Terzaghi design methods for anchored walls for input or calculated factor of safety. Adjusts net pressures for specified water pressure distribution.

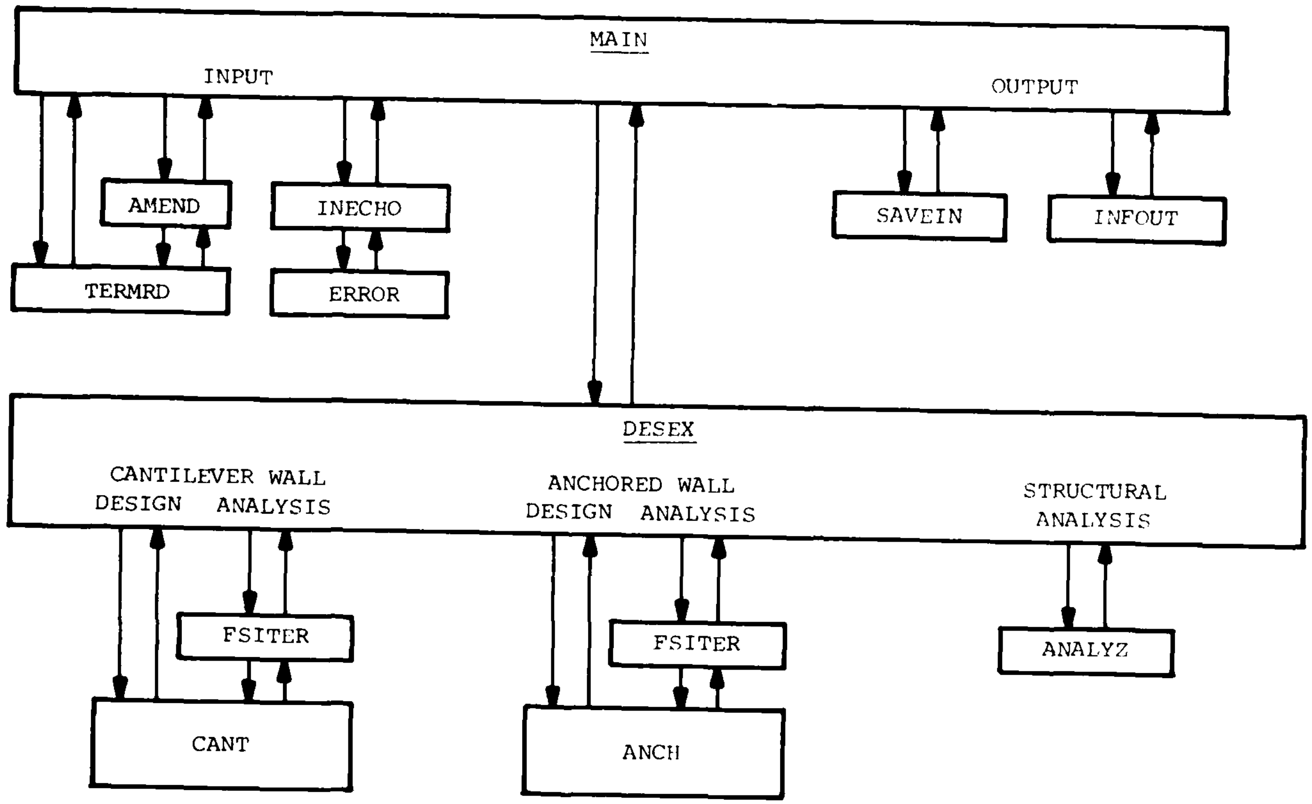
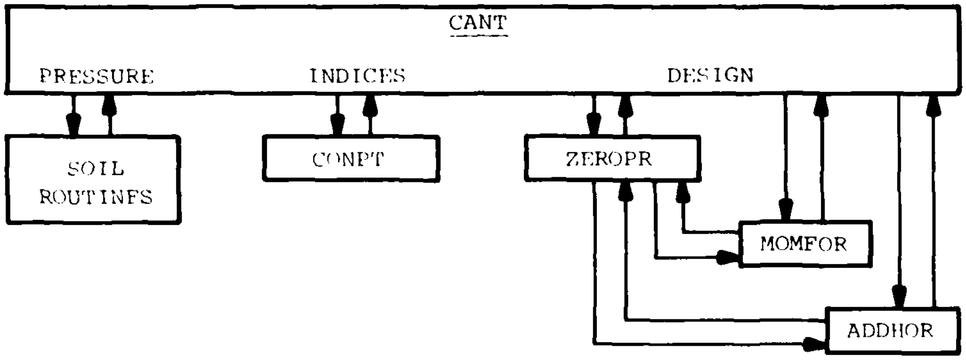
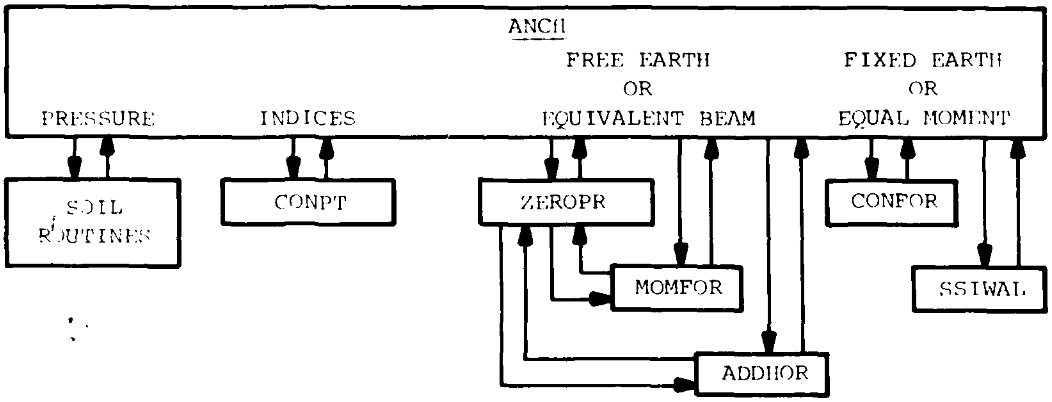


Figure 12. Principal function flow diagram



(a) Cantilever Wall Design



(b) Anchored Wall Design

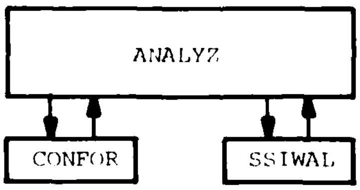
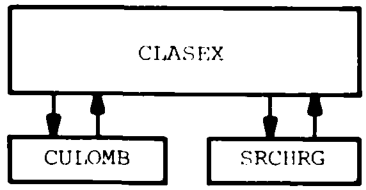
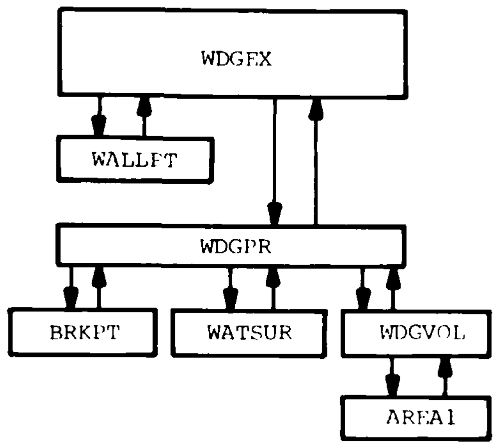


Figure 13. Summary flow diagrams for design/analysis



(a) Coefficient Method



(b) Wedge Method

Figure 14. Summary flow diagrams for soil routines

64. ANCHFE: Determines required penetration for Fixed Earth Method for anchored walls for input or calculated factor of safety. Adjusts net pressure for specified water pressure distribution.

65. CANT: Determines required penetration for cantilever wall for input or calculated factor of safety. Adjusts net pressures for specified water pressure distribution.

66. ANALYZ: Sets up equivalent concentrated forces for structural analysis of cantilever walls and for anchored walls designed by Free Earth and Equivalent Beam Methods. Determines maximum bending moments and displacements. Tabulates results for output.

67. CLASEX: Sets up four soil pressure distributions for systems in which the coefficient method is used. Combines soil pressure distributions and surcharge pressure distribution into net pressure distributions.

68. CULOMB: Calculates active and passive Coulomb earth pressure coefficients and active and passive earth pressures at layer boundaries, water surfaces, and other control points on wall.

69. SRCHRG: Calculates pressures due to surcharges by theory of elasticity equations when soil pressures are determined by the coefficient method.

70. WDGEX: Sets up four soil pressure distributions when wedge method is used. Combines soil pressure distributions into net pressure distributions.

71. WALLPT: Locates calculation points on wall when wedge method is used.

72. WDGPR: Calculates active and passive forces for each calculation point by wedge method. Converts active and passive forces to pressures.

73. WDGVOL: Calculates volume of failure wedge defined by failure surface emanating from a calculation point.

74. BRKPT: Utility subroutine for wedge method. Locates intersection of sloping soil boundaries with irregular soil surface.

75. WATSUR: Utility subroutine for wedge method. Called when water surface intersects irregular soil surface to determine transition from unsubmerged to submerged conditions for soil unit weight calculations.

76. AREA1: Utility subroutine for wedge method. Calculates area of polygon from array of x- and y-coordinates of corners.

77. CONPT: Utility subroutine to determine indices of calculation points at intersections of left and right soil surfaces with wall, and at anchor. Adds earthquake water pressures and general horizontal applied pressure distribution to net pressures.

78. ZEROPR: Utility subroutine to determine location of first point of zero net pressure at or below leftside surface. Calculates resultants of all forces above point of zero net pressure.

79. MOMFOR: Utility subroutine to calculate moment about a reference point and resultant force of a trapezoidal pressure distribution.

80. ADDHOR: Utility subroutine to calculate moment about a reference point and sum of all horizontal line loads between prescribed elevations on wall.

81. CONFOR: Utility subroutine to convert net pressure distribution to equivalent concentrated loads.

82. SUMFOR: Utility subroutine to calculate resultant force and moment about a reference elevation of a net pressure diagram.

83. SSIWALL: Performs structural analysis of wall by one-dimensional finite element method.

84. TERMRD: Prints prompting messages and reads input data from user terminal.

85. INECHO: Reads input data from data file. Checks input data for errors. Echoes input data to user terminal or to output file.

86. ERROR: Prints fatal error messages to user terminal for input data errors.

87. DCIFR: Utility subroutine to locate nonblank characters on a line of alphanumeric input data.

88. AMEND: Prints prompting messages and controls for changing previously supplied input data.

89. SAVEIN: Writes input data supplied from user terminal to permanent file in input file format.

90. INFOUT: Prints summary of results to user terminal. Through interactive questions and user responses, prints output data as requested to user terminal or writes to output file.

91. SOILPR: Sets up active and passive soil pressures for optional printing to terminal during design.

92. SHUFLE: Utility subroutine for SOILPR to set up active and passive soil pressure arrays obtained from coefficient method.

Input Data

93. Input data may be provided either interactively from the user's terminal or from a previously prepared data file. When data are input from the terminal during execution, the program provides prompting messages to indicate the type and amount of input data to be provided. The characteristics of a previously prepared data file are described in the Input Data Guide contained in Appendix A.

94. Whenever an input sequence is completed, either from a data file or from user terminal, the program provides an opportunity to change any or all parts of the input data in an Editing mode.

95. Whenever any input data are entered from the user's terminal, the program provides for saving the existing input data in a permanent file.

Output Data

96. The user has several options regarding the amount and destination of the output from the program. The three basic parts of the output and user option pertaining to each part are described below.

97. ECHOPRINT OF INPUT DATA: A complete tabulation of all input data as read from the user terminal or from an input file. The user may direct this section of the output to the terminal, to an output file, to both, or may elect to omit the echoprint entirely.

98. SUMMARY OF RESULTS: A tabulation of design penetration from the "Design" mode or the factor of safety from the "Analysis" mode with maximum bending moment and deflection for a cantilever wall; or a tabulation of design penetration or factor of safety, maximum bending moment and deflection, and anchor force for each method exercised for an anchored wall. This summary is always printed to the user's terminal. The

user may also direct this summary to the same or to a different file than that used for echoing the input data.

99. COMPLETE RESULTS: A complete tabulation of the elevation, bending moment, shear force, deflection, and final net pressure at each calculation point on the wall. Whenever dual values exist at a single point (e.g., discontinuities in soil pressures in stratified soils, or sudden changes in shear at the anchor or at points of application of horizontal line loads), two or more lines of results appear for that point giving the values immediately above and below the discontinuity. The user may omit this section of the output, direct it to the terminal, or write it to the output file containing the summary of results. For anchored walls the user may elect to print/write the complete tabulation of results for any or all of the design methods exercised.

Units and Sign Conventions

100. Units and sign conventions for forces and displacements used for calculations and output of results are shown in Table 1.

Tolerances

101. In either the "Design" or "Analysis" mode, repetitive trial and correction solutions are performed. A final solution is considered to be obtained when the force and dimension tolerances listed in Table 2 are satisfied.

Table 1

Units and Sign Conventions

Item	Units	Sign Convention
Horizontal Distances	FT	Always Positive
Elevations	FT	Positive or Negative decreasing downward
Modulus of Elasticity	PSI	
Wall Moment of Inertia	$IN.^4$	
Soil Unit Weight	PCF	
Angle of Internal Friction	DEG	
Cohesion	PSF	
Angle of Wall Friction	DEG	Positive or Negative
Horizontal Line Loads	PLF	Positive to Left
Horizontal Applied Pressures	PSF	Positive to Left
Vertical Line Surcharges	PLF	Positive downward
Strip, Ramp, Triangular, or Uniform Surcharges	PSF	Positive downward
Water Unit Weight	PCF	
Earthquake Acceleration	G's	Always Positive
Pressures	PSF	Positive to left
Bending Moment	LB-FT/FT	Positive if produces compression on right side of wall
Shear Force	LB/FT	Positive acts to right on top end of vertical wall section
Deflection	IN.	Positive to left
"Scaled" Deflection	$LB\text{-}IN.^3$	Positive to left
Rotation	RADIANS	Positive counterclockwise
"Scaled" Rotation	$LB\text{-}IN.^2$	Positive counterclockwise
Anchor Force	LB/FT	Always Tension

Table 2

Tolerances for Convergence

Wall Type	Mode	Method	
Cantilever	Design	--	Resultant Force $\leq$ 0.1 LB Resultant Moment $\leq$ 0.1 LB-FT
Cantilever	Analysis	--	Design elevation of bottom of wall for calculated factor of safety within 0.01 FT of input bottom of wall elevation
Anchored	Analysis	All	
Anchored	Design	Free Earth	Resultant Moment $\leq$ 0.1 LB-FT
Anchored	Design	Fixed Earth Terzaghi	"Scaled" angular rotation of tangent from vertical at wall bottom $\leq$ 0.1 LB-IN.
Anchored	Design	Equivalent Beam	Resultant Moment $\leq$ 0.1 LB-FT
Anchored	Design	Equal Moment	Difference in absolute values of maximum positive and negative bending moments $\leq$ 0.1 LB-FT

PART VI: EXAMPLE SOLUTIONS

General

102. Numerous wall/soil systems have been investigated to test and verify the computational procedures used in the program. Example solutions and supporting information are presented in Appendix B for cantilever walls and in Appendix C for anchored walls. These examples only input the computational processes of the program. The interactive graphics capabilities of the program to help in data input and output interpretation will be presented in Report 2 of this series. In all examples herein, any program prompts for graphics information will be answered with a negative reply but will be shown here to make the user aware that the graphics package will be available.

Cantilever Walls

Problem "CANT1"

103. The cantilever retaining wall shown in Figure B1A was designed for a factor of safety of 1.0. Initiation of a run using program SHTWAL is shown on page B5. As indicated, input data were previously stored in permanent data file "CANT1," listed on page B6. An echoprint of the data is shown on pages B7 and B8. Program prompting messages (upper case) and user response (lower case) are shown. In the "Design" mode, the active and passive soil pressures on each side of the wall may be printed at the user's terminal, as shown on pages B9 and B10. Following completion of the solution, a summary of results, page B11, is always printed to the user's terminal. This summary will also appear in an output file when an output file is created at the user's option. The user may terminate the output at this point or may request a complete tabulation of results as shown on pages B12 and B13. Plots of these results are shown in Figures B1B, B1C, and B1D.

104. A solution for design penetration for this problem is presented in Reference 1. Hand calculations for design penetration as well as net pressures and maximum bending moment are shown on pages B14 through B19. Numerical values shown in all hand calculations have been truncated at

two significant figures beyond the decimal. This truncation accounts for the differences between results obtained by hand and by the program.

Problem "CANT1A"

105. Problem "CANT1A" illustrates potential use of the program in an actual design situation. For initial design the sheet pile section (i.e., wall moment of inertia) will not be known. Hence the program must be exercised in the "DESIGN" mode to determine penetration, maximum bending moment, and maximum scaled deflection.

106. The input data for Problem "CANT1" were edited as shown on pages B21 and B22 to perform an "Analysis" of the wall at design penetration using a sheet pile section having a moment of inertia equal to 220.4 $in.^4$/ft of wall. An echo of the amended input is shown on pages B23 and B24. The significant differences in results from those of Problem "CANT1" are that the factor of safety rather than penetration is reported in the summary, page B25, and the deflections are reported in inches instead of scaled values in both the summary and complete results, page B26.

Problem "CANT2"

107. The floodwall shown in Figure B2A was designed for an earthquake acceleration equal to 0.1 g's. Input data for this problem were entered from the user's terminal at execution. Program promptings (upper case) and user response (lower case) are shown on pages B29 through B31. The input data were saved in a permanent file. A listing of the file generated by the program is shown on page B32. Results from the program are shown on pages B33 and B34 and in Figure B2B.

108. Hand calculations to further illustrate the process used in the program to simulate earthquake effects on soil and water pressures and to verify program results are shown on pages B35 through B39.

Problem "CANT3"

109. Calculation of net active pressures for the stratified soil system shown in Figure B3A by the coefficient method results in a sudden change in net pressure at El -10 from 891 PSF to 1891 PSF, Figure B3B. Equilibrium requirements for conventional cantilever wall design cannot be satisfied if the final design pressure distribution is limited to either of these extremes. The program permits the final design pressure

at the discontinuity to assume an intermediate value as necessary to satisfy equilibrium, Figure B3B.

110. Input data were read from a data file, listed on page B42. Program results are shown on pages B43 and B44. Hand calculations for this problem are contained on pages B45 through B50.

Problem "CANT4"

111. The system shown in Figure B4A requires the use of the wedge method for calculation of soil pressures. The resulting design pressure distribution is shown in Figure B4B. A listing of the input data file for this problem is shown on page B54. Active and passive soil pressures are shown on pages B55 and B56. Results are contained on pages B57 and B58.

Anchored Walls

Problem "ANCH1"

112. The anchored wall shown in Figure C1A was designed by all five methods incorporated in the program. Input data were read from the file listed on page C6. An echo of input data is shown on pages C7 and C8. Results are shown on pages C9 through C20 along with program prompts to determine the type of data desired by the user. Results are plotted in Figures C1B through C1D.

113. A solution for design penetration of this wall by the Free Earth method is presented in Reference 1. Hand calculations for design penetration, maximum bending moment, and anchor force for the Free Earth, Equivalent Beam, and Equal Moment methods are included on pages C21 through C27. Differences between hand calculated values and program results are again attributable to truncation of the numerical values in the hand calculations.

Problem "ANCH1A"

114. The editing feature of the program was used to alter the input data for Problem "ANCH1" to perform an "ANALYSIS" of the wall. The analysis was performed for a sheet pile section with a moment of inertia equal to 220.4 in.^{4}/ft of wall with the bottom of the wall at El -14.5 (i.e., penetration equal to 14.5 ft). The summary of results, page C29, indi-

cates the factor of safety associated with each design method. Complete results for the Free Earth and Fixed Earth methods are shown on pages C30 through C33.

Problem "ANCH2"

115. The anchored wall shown in Figure C2A was designed by all five methods. In addition to soil and water forces, the wall was subjected to a horizontal line load equal to 1000 lb/ft of wall at the top of the wall. Input data for this problem were entered from the user's terminal at execution as shown on pages C36 through C38. An echo of the input data is shown on pages C39 through C41. The summary of results is shown on page C42. Complete results for all methods are contained on pages C44 through C53. Hand calculations for verification of the results are shown on pages C54 through C60.

Problem "ANCH3"

116. The effect of seepage is illustrated in the design of the anchored wall shown in Figure C3. The seepage gradient of 1/3 FT/FT results in total dissipation of the twenty foot head on the right side at elevation -20. Soil submerged unit weights on either side of the wall above elevation -20 are affected by seepage. Static water is assumed below elevation -20. Input data for this problem were read from the data file listed on page C63 and echoprinted on pages C64 and C65. Results are contained on pages C66 through C75. Hand calculations for verification of the program results are included on pages C76 through C78.

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4. Richart, F. E., Jr., "Anchored Bulkhead Design by Numerical Method," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 86, No. SM1, February, 1960.

5. Terzaghi, K., Theoretical Soil Mechanics, John Wiley & Sons, Inc., New York, 1943.

APPENDIX A: INPUT DATA GUIDE

Notes and General Requirements

for Wall Description

1. Coordinate System

   a. The wall is assumed to be vertical.

   b. All elevations and distances are assumed to be given in feet.

   c. All vertical dimensions are given as elevations with respect to an arbitrary datum. Elevations increase toward the top of the wall.

   d. All horizontal dimensions are given as the positive distance in feet from the wall, increasing away from the wall. There are no negative horizontal distances.

   e. Impending rotation of the wall is assumed to be counterclockwise for cantilever walls and clockwise for anchored walls.

2. Top of Wall

   a. The elevation of the top of the wall must be at or above the intersection of the rightside surface with the wall (i.e., TOPEL $\geq$ SURELR(1), Figure A2).

3. Anchor

   a. For an anchored wall, a horizontal anchor is assumed.

   b. The anchor must be at or below the elevation of the top of the wall (i.e., ANCHEL $\leq$ TOPEL, Figure A1).

4. Bottom of Wall

   a. The elevation of the bottom of the wall, BOTEL (Figure A1) is determined in the "Design" mode.

   b. The elevation of the bottom of the wall, BOTEL (Figure A1) must be provided in the "Analysis" mode.

5. Rightside Soil Surface (Figure A2)

   a. The general rightside surface is assumed to be described by pairs of coordinates giving the elevation and distance from the wall for up to fifteen (15) points on the surface. The surface between adjacent points is assumed to be a straight line.

      a(1) The first point is at the intersection of the surface and the wall. The elevation of the first point must be at or below the top of the wall.

      a(2) If only one (1) surface point is provided, a horizontal rightside surface is assumed.

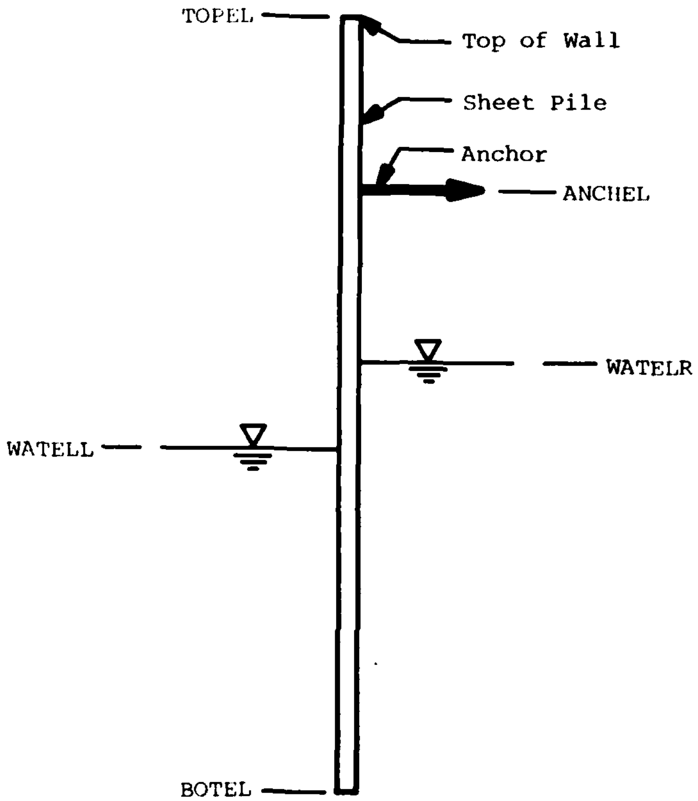
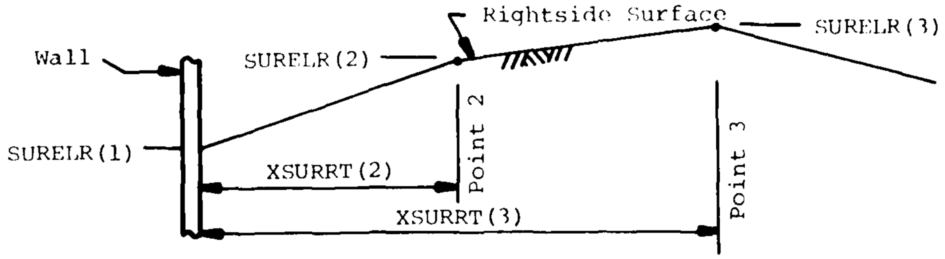
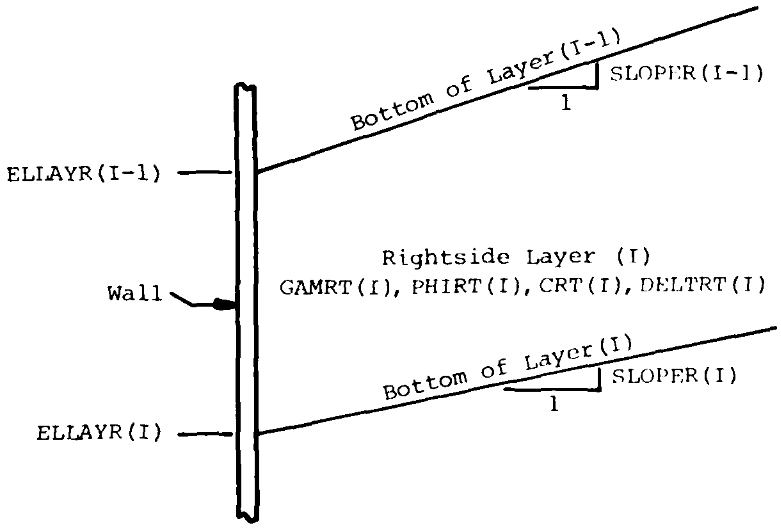


Figure A1. Data names for wall, water, and anchor elevations and horizontal line loads



(a) Rightside Surface Coordinates



(b) Rightside Layer Data

Figure A2. Data names for rightside soil

a(3) The rightside surface is assumed to extend horizontally ad infinitum beyond the last surface point provided.

a(4) The slope of every segment of the surface must be less than or equal to the effective angle of internal friction for the top rightside soil layer.

7. Rightside Soil Layers (see Figure A2)

a. The soil on the rightside of the wall is assumed to be composed of one (1) to fifteen (15) soil layers. Soil properties as follow are assumed to be constant within each layer.

a(1) Unit weight, GAMRT, (PCF) input is assumed to be for unsubmerged soil. Submerged unit weight is determined from the position of the water surface on the rightside.

a(2) Angle of internal friction, PHIRT, (DEG) must be greater than or zero if CRT (see next paragraph) is equal to zero.

a(3) Cohesion, CRT, (PSF) must be greater than zero if PHIRT is equal to zero.

a(4) Angle of wall friction, DELTRT, (DEG).

b. Adjacent soil layers are assumed to be separated by a straight line which extends ad infinitum from the wall. The boundary between layers is associated with the layer above and is described by

b(1) The elevation, ELLAYR, at which the boundary intersects the wall.

b(2) The slope, SLOPER, of the wall expressed in feet of rise per foot. A positive slope extends up away from the wall.

b(3) Layer boundary lines may not intersect (i.e., must be parallel or diverge away from the wall).

c. The last soil layer provided is assumed to extend ad infinitum downward.

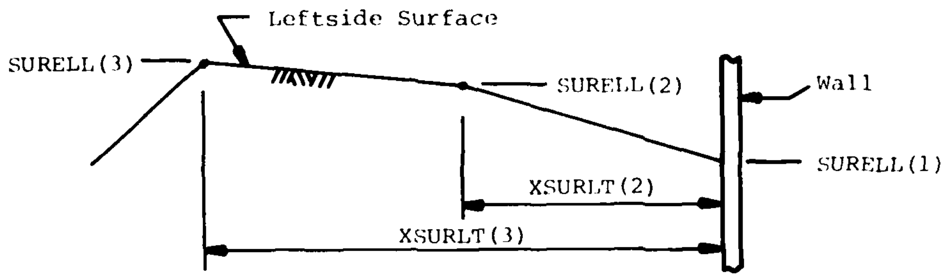
8. Leftside Soil Surface (see Figure A3)

a. The general leftside surface is assumed to be described by pairs of coordinates giving the elevation and distance from the wall for up to fifteen (15) points on the surface. The surface between adjacent points is assumed to be a straight line.

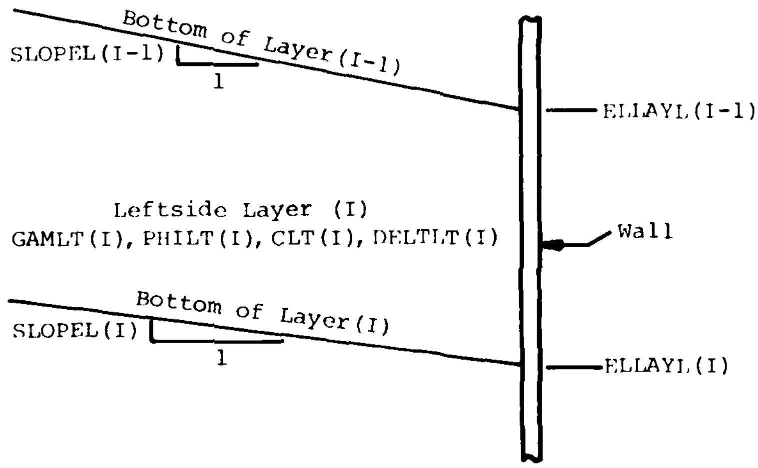
a(1) The first point is at the intersection of the surface and the wall and must be at or below the top of the wall.

a(2) If only one (1) surface point is provided, a horizontal surface is assumed.

a(3) The leftside surface is assumed to extend horizontally ad infinitum beyond the last surface point provided.



(a) Leftside Surface Coordinates



(b) Leftside Layer Data

Figure A3. Data names for leftside soil

a(4) The slope of every segment of the leftside surface must be less than or equal to the effective angle of internal friction for the top leftside soil layer.

9. Leftside Soil Layers (see Figure A3)

a. The soil on the leftside of the wall is assumed to be composed of one (1) to fifteen (15) soil layers. Soil properties as follow are assumed to be constant within each layer.

a(1) Unit weight, GAMLT, (PCF) is assumed to be for unsubmerged soil. Submerged unit weight will be determined from the position of the leftside water surface.

a(2) Angle of internal friction, PHILT, (DEG) must be greater than zero if CLT (see next paragraph) is equal to zero.

a(3) Cohesion, CLT, (PSF) must be greater than zero if PHILT is equal to zero.

a(4) Angle of wall friction, DELTLT, (DEG).

10. Water Data

a. When seepage effects are not included, water on either side of the wall may be at any elevation.

b. When seepage effects are included, the following must be observed.

b(1) Water elevation on right side must be above water elevation on left side.

b(2) Seepage is assumed to commence on the right side at the lower of WATELR and SURELR(1).

b(3) Seepage is assumed to cease on the left side at the lower of WATELL and SURELL(1).

b(4) The value of seepage gradient provided as input must be positive, less than one; and must not result in zero net water pressure above the point at which seepage ceases on the left side.

11. Vertical Surcharge Loads on Rightside Surface (see Figure A4)

a. Load units are assumed to be pounds per lineal foot (PLF) for line loads and pounds per square foot (PSF) for distributed loads.

b. Zero (0) to four (4) line loads may be applied at any point on the rightside surface.

c. Zero (0) or one (1) distributed surcharge load may be applied as shown in Figures A4b, A4c, A4d, and A4e.

c(1) A uniform distributed load (Figure A4b) may only be applied to a horizontal surface.

c(2) Distributed strip and triangular loads must be applied to a horizontal segment of the rightside surface.

c(3) A ramp load may be applied only on a horizontal surface or on the extension of a final horizontal segment of an irregular surface.

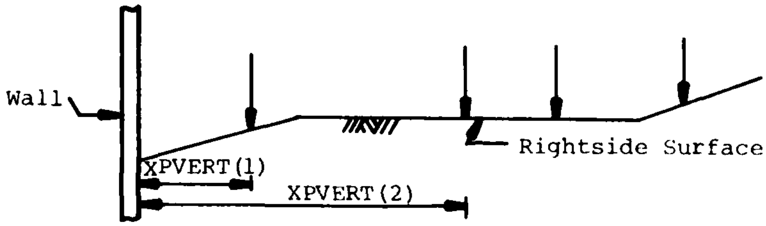
c(4) A rightside surface point may not lie within the limits of a distributed load.

12. Horizontal Line Loads (see Figure A5a)

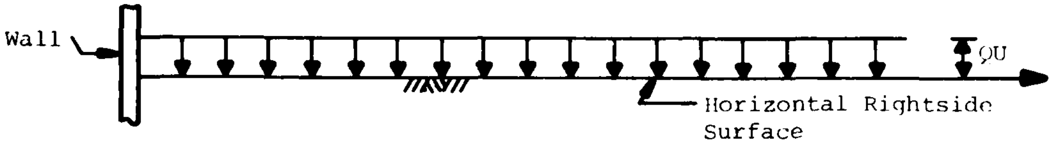
a. Load units are assumed to be pounds per lineal foot (PLF).

b. Zero (0) to four (4) horizontal line loads may be applied anywhere at or below the top of the wall.

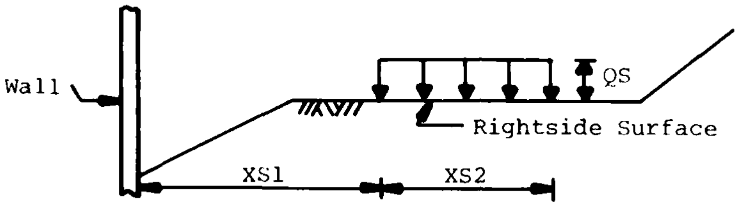
c. Positive horizontal loads act to the left.



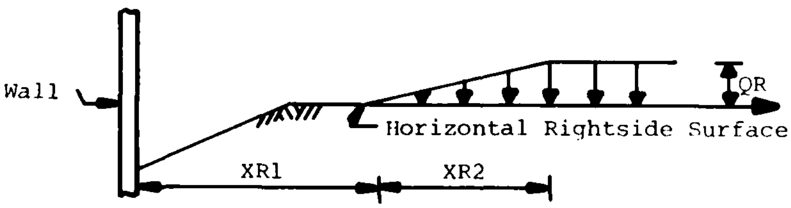
(a) Vertical Line Loads



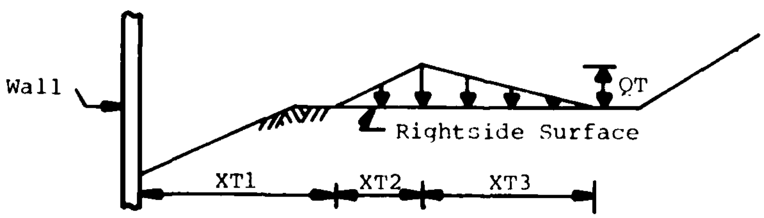
(b) Uniform Load



(c) Strip Load

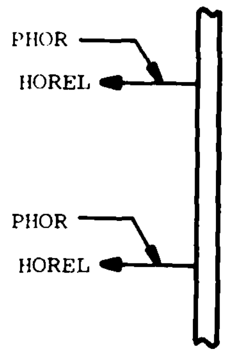


(d) Ramp Load

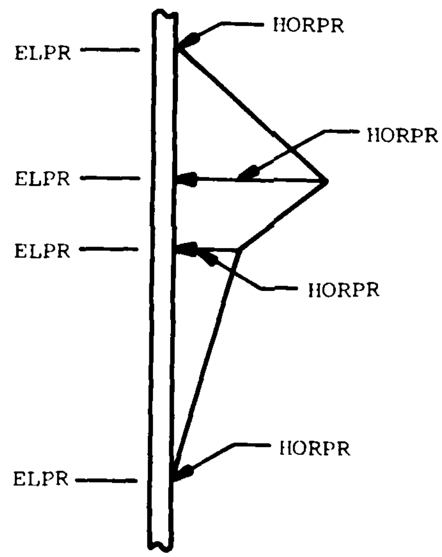


(e) Triangular Load

Figure A4. Data names for surcharge loads



(a) Horizontal Line Loads



(b) Horizontal Distributed Load

Figure A5. Horizontal applied loads

13. Horizontal Applied Pressure Distribution (see Figure A5b)

   a. A general applied pressure distribution is assumed to be described by pairs of values giving the elevation and

magnitude of pressure for up to twelve points. The distribution is assumed to be linear between adjacent points.

b. Points must be supplied in sequential order with elevations progressing downward.

c. Dual pressure values at a single elevation are not permitted.

d. The elevation of the first point must be at or below the top of the wall.

e. All pressure values must have the same sign (either positive or negative).

f. At least two points are required to describe a distribution.

g. Pressure units are assumed to be pounds per square foot (PSF).

14. Input Data

a. Input data may be entered during execution from the user's terminal or may be stored in a permanent file before the program is executed. The file name must be one (1) to six (6) alphanumeric characters beginning with an alphabetic character.

b. Data are read in free field format.

b(1) Data items on lines designated (alphanumeric) must be separated by one or more blanks.

b(2) Data items on lines designated (numeric) may be separated by commas.

b(3) Integer number values must be of form NNNN.

b(4) Real number values may be of form XXXX, XX.XX, X.XXE+ee.

c. Each line in a data file must begin with a nonzero integer line number denoted LN below. Line numbers are not required when data are entered during execution from the user's terminal.

d. Input data lines must be in the sequence described below. Line descriptors enclosed in brackets [ ] or braces { } may not be required.

e. Lower case words enclosed by single quotes, in the description below indicate alphanumeric information.

f. All alphanumeric keywords may be abbreviated with the underlined character(s).

15. Input Data Sequence and Description

a. Header--One (1) to four (4) lines are provided for identifying the run.

a(1) Header Line 1 (alphanumeric)

(a) Contents

[LN] NLINES 'heading'

(b) Definitions

[LN] = line number (not required if data entered during execution from user's terminal)

NLINES = total number of header lines = integer 1 to 4

'header' = any alphanumeric information

(c) Total characters on Header Line 1 including LN, NLINES, 'heading,' and embedded blanks must be ≤ 80. Blank 'heading' is not permitted.

a(2) Header Lines 2 to NLINES ([data] not required if NLINES = 1) (alphanumeric)

(a) Contents

[LN]['heading']

(b) Total characters including LN, 'heading,' and embedded blanks must be ≤ 80. Blank 'heading' is not permitted.

b. Wall Type, Mode, Method--One (1) Line (alphanumeric)

b(1) Contents

[LN] 'type' 'mode' [nmethods] ['methods']

b(2) Definitions

'type' = CANTILEVER or ANCHORED

'mode' = ANALYSIS or DESIGN

[nmethods] (not required if 'type' = CANTILEVER)
= integer 1 to 5 indicating the number of methods described below to be used in ANALYSIS or DESIGN of an anchored wall

['methods'] (not required if 'type' = CANTILEVER)
1 to 5 of the following codes

= FR for Free Earth Method

= FI for Fixed Earth Method

= EB for Equivalent Beam Method

= EM for Equal Moment Method

= TE for Terzaghi Method

c. Wall Description--One (1) Line (numeric)

c(1) Contents if 'type' = CANTILEVER and 'mode' = DESIGN

[LN] TOPEL FS

c(2) Contents if 'type' = CANTILEVER and 'mode' = ANALYSIS

[LN] TOPEL BOTEL EMOD SECMOM

c(3) Contents if 'type' = ANCHORED and 'mode' = DESIGN

[LN] TOPEL ANCHEL FS

c(4) Contents if 'type' = ANCHORED and 'mode' = ANALYSIS

[LN] TOPEL ANCHEL BOTEL EMOD SECMOM

c(5) Definitions

TOPEL = elevation of top of wall (FT)

ANCHEL = elevation of anchor (FT)

BOTEL = elevation of bottom of wall (FT)

FS = factor of safety

EMOD = modulus of elasticity (PSI)

SECMOM = moment of inertia (IN^4)

d. Rightside Soil Description--Three (3) to twenty-two (22) lines

d(1) Control--One (1) line (numeric)

(a) Contents

[LN] NSURRT NLAYRT

(b) Definitions

NSURRT = number of rightside surface points (1 to 15)

NLAYRT = number of rightside soil layers (1 to 15)

d(2) Rightside Surface Point Coordinates--({data} not required if NSURRT = 1) (numeric)

(a) Surface Point Elevations, NSURRT Values, five (5) per line

[LN] SURELR(1) {SURELR(2)...SURELR(NSURRT)}

(b) Surface Point X-Coordinates, NSURRT-1 Values, five (5) per line, omit entire line if NSURRT = 1

[LN] {XSURRT(2)...XSURRT(NSURRT)}

(c) Definitions

SURELR(I) = elevation of Ith surface point (FT)

XSURRT(I) = distance from wall to Ith surface point (FT)

Point numbers start with 1 at wall and proceed in sequence away from wall

d(3) Rightside Soil Layer Data--NLAYRT lines (numeric) ({data} not required for I = NLAYRT) (Layer 1 is surface layer, layers proceed sequentially downward)

(a) Contents

[LN] GAMRT(I) PHIRT(I) CRT(I) DELTRT(I) {ELLAYR(I), SLOPER(I)}

(b) Definitions

GAMRT(I) = unsubmerged unit weight (PCF)

PHIRT(I) = angle of internal friction (DEG)

CRT(I) = cohesion (PSF)

DELTRT(I) = angle of wall friction (DEG)

ELLAYR(I) = elevation at wall of boundary between layer I and layer I + 1 (FT)

SLOPER(I) = slope of boundary between layer I and layer I + 1 (FT) (interpreted as rise per foot, positive if boundary slopes up away from wall)

e. Leftside Soil Description--Three (3) to twenty-two (22) lines

e(1) Control--One (1) line (numeric)

(a) Contents

[LN] NSURLT NLAYLT

(b) Definitions

NSURLT = number of leftside surface points (1 to 15)

NLAYLT = number of leftside soil layers (1 to 15)

e(2) Leftside Surface Point Coordinates--({data} not required if NSURLT = 1) (numeric)

(a) Surface Point Elevations, NSURLT Values, five (5) per line

[LN] SURELL(1) {SURELL(2)...SURELL(NSURLT)}

(b) Surface Point X-Coordinates, NSURLT-1 Values, five (5) per line, omit entire line if NSURLT = 1

[LN] {XSURLT(2)...XSURLT(NSURLT)}

(c) Definitions

SURELL(I) = elevation of Ith surface point (FT)

XSURLT(I) = distance from wall to Ith surface (FT)

Point numbers start with 1 at wall and proceed in sequence away from wall

e(3) Leftside Soil Layer Data--NLAYLT lines ({data} not required for I = NLAYLT)

(a) Contents

[LN] GAMLT(I) PHILT(I) CLT(I) DELTLT(I) {ELLAYL(I), SLOPEL(I)}

(b) Definitions

GAMLT(I) = unsubmerged unit weight (PCF)

PHILT(I) = angle of internal friction (DEG)

CLT(I) = cohesion (PSF)

DELTLT(I) = angle of wall friction (DEG)

ELLAYL(I) = elevation at wall of boundary between layer I and layer I + 1 (FT)

SLOPEL(I) = slope of boundary between layer I and layer I + 1 (FT) (interpreted as rise per foot, positive if boundary slopes up away from wall)

f. Water Data--One (1) line (numeric)

f(1) Contents

[LN] WATELR WATELL GAMWAT SEEP

f(2) Definitions

WATELR = water elevation on rightside (FT)

WATELL = water elevation on left side (FT)

GAMWAT = unit weight of water (PCF) (If GAMWAT input as zero, default to GAMWAT = 62.4. If GAMWAT input as negative, water effects are not considered)

SEEP = seepage gradient FT/FT)

g. Vertical Loads on Rightside--One (1) to three (3) lines (alphanumeric)

g(1) Control--One (1) line

(a) Contents

[LN] NPVERT 'distributed load'

(b) Definitions

NPVERT = number of vertical concentrated loads (0 to 4)

'distributed load' = NONE if no distributed load
= UNIFORM for uniform load
= STRIP for strip load
= RAMP for ramp load
= TRIANGULAR for triangular load

g(2) Vertical Line Loads--Zero (0) or one (1) line ([data] not required if NPVERT = 0)

(a) Contents

[LN] [XPVERT(I) PVERT(I)...XPVERT(NPVERT) PVERT(NPVERT)]

(b) Definitions

XPVERT(I) = distance of Ith load from wall (FT)

PVERT(I) = magnitude of Ith load (PLF)

g(3) Distributed Vertical Load--Zero (0) or one (1) line (numeric)
([data] not required if 'distributed load' = NONE)
({data} not required if 'distributed load' ≠ TRIANGULAR)

(a) Contents

[LN] [X1 X2 {X3} Q]

(b) Definitions

X1 = distance from wall to start of STRIP, RAMP, or TRIANGULAR load (FT)

X2 = width of STRIP distribution (FT)
= width of increasing load for RAMP or TRIANGULAR (FT)

X3 = width of decreasing load for TRIANGULAR (FT)

Q = magnitude of maximum distributed load (PSF)

Only LN and Q are required for UNIFORM distributed load

h. Horizontal Loads--One (1) to five (5) lines (numeric)

h(1) Control--One (1) line

(a) Contents

[LN] NPHOR NHORPR EQACC

(b) Definitions

NPHOR = number of horizontal line loads (0 to 4)

NHORPR = number of points for horizontal distribution = integers 0 or 2 to 12

EQACC = earthquake acceleration (G's), positive number, $0.0 \leq$ EQACC < 1.0

h(2) Horizontal Line Loads--Zero (0) or one (1) line ([data] not required if NPHOR = 0) (numeric)

(a) Contents

[LN] [HOREL(1) PHOR(1)...HOREL(NPHOR) PHOR(NPHOR)]

(b) Definitions

HOREL(I) = elevation of Ith load (FT)

PHOR(I) = magnitude of Ith load (PLF)

h(3) Horizontal Pressure Distribution--Zero (0) to three (3) lines
([data] not required if NHORPR = 0) (numeric)
NHORPR pairs of values, four (4) pairs per line

(a) Contents

[LN] [ELPR(1) HORPR(1)...ELPR(NHORPR) HORPR(NHORPR)]

(b) Definitions

ELPR(I) = elevation of Ith pressure point (FT)

HORPR(I) = horizontal pressure at ELPR(I) (PSF)

Point numbers start at top point and proceed sequentially downward

Abbreviated Input Guide

16. Notation

a. Data items enclosed in brackets [ ] may not be required

b. Data items enclosed in braces { } indicate choose one (or more)

17. Input

a. Header--One (1) to four (4) lines

LN NLINES 'heading'

[LN 'heading']

[LN 'heading']

[LN 'heading']

b. Wall Type, Mode, Method--One (1) line

$$[\mathrm{LN}] \begin{Bmatrix} \underline{\mathrm{C}}\mathrm{ANTILEVER} \\ \underline{\mathrm{A}}\mathrm{NCHORED} \end{Bmatrix} \begin{Bmatrix} \underline{\mathrm{D}}\mathrm{ESIGN} \\ \underline{\mathrm{A}}\mathrm{NALYSIS} \end{Bmatrix} [\mathrm{NMETH}] \begin{bmatrix} \underline{\mathrm{FR}} \\ \underline{\mathrm{FI}} \\ \underline{\mathrm{EB}} \\ \underline{\mathrm{EM}} \\ \underline{\mathrm{TE}} \end{bmatrix}$$

c. Wall Description--One (1) line

LN TOPEL {ANCHEL} {BOTEL} {EMOD} {SECMOM} {FS}

d. Rightside Soil Description--Three (3) to twenty-two (22) lines

d(1) Control--One (1) line

LN NSURRT NLAYRT

d(2) Rightside Surface Point Coordinates--One (1) to six (6) lines

LN SURELR(1) [SURELR(2)...SURELR(NSURRT)]
[LN XSURRT(2)...XSURRT(NSURRT)]

d(3) Rightside Soil Layer Data--One (1) to fifteen (15) lines

LN GAMRT(I) PHIRT(I) CRT(I) DELTRT(I) [ELLAYR(I) SLOPER(I)]

e. Leftside Soil Description--Three (3) to twenty-two (22) lines

e(1) Control--One (1) line

LN NSURLT NLAYLT

e(2) Leftside Surface Point Coordinates--One (1) to six (6) lines

LN SURELL(1) [SURELL(2)...SURELL(NSURLT)]
[LN XSURLT(2)...XSURLT(NSURLT)]

e(3) Leftside Soil Layer Data--One (1) to fifteen (15) lines

LN GAMLT(I) PHILT(I) CLT(I) DELTLT(I) [ELLAYL(I) SLOPEL(I)]

f. Water Data--One (1) line

LN WATELR WATELL GAMWAT SEEP

g. Vertical Loads on Rightside--One (1) to three (3) lines

g(1) Control--One (1) line

LN NPVERT $\left\{ \begin{array}{l} \underline{N}\text{ONE} \\ \underline{U}\text{NIFORM} \\ \underline{S}\text{TRIP} \\ \underline{R}\text{AMP} \\ \underline{T}\text{RIANGULAR} \end{array} \right\}$

g(2) Vertical Line Loads--Zero (0) or one (1) line

[LN XPVERT(1) PVERT(1)...XPVERT(NPVERT) PVERT(NPVERT)]

g(3) Distributed Vertical Load--Zero (0) or one (1) line

[LN {X1} {X2} {X3} Q]

h. Horizontal Loads--One (1) or two (2) lines

h(1) Control--One (1) line

LN NPHOR NHORPR EQACC

h(2) Horizontal Line Loads--Zero (0) or one (1) line

[LN HOREL(1) PHOR(1)...HOREL(NPHOR) PHOR(NPHOR)]

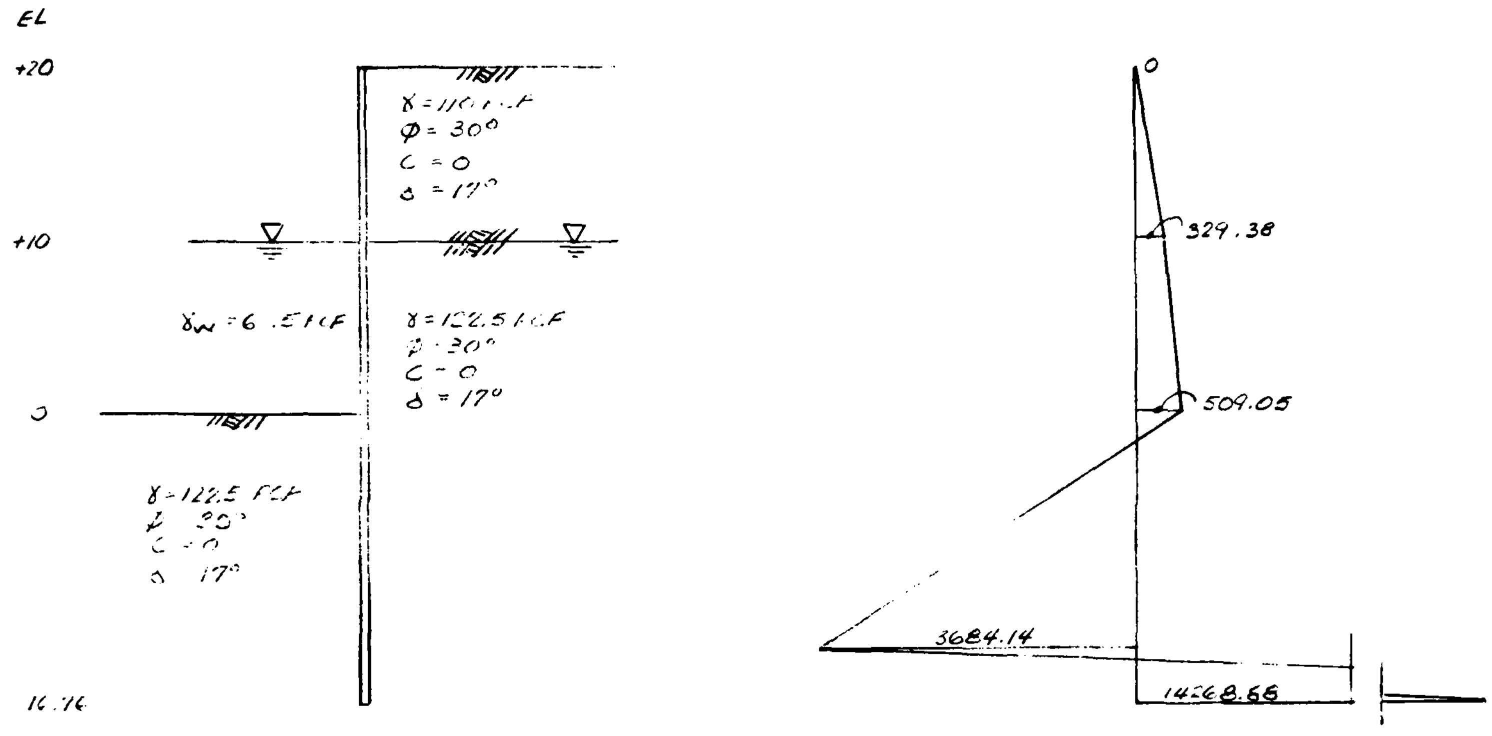
h(3) Horizontal Pressure Distribution--Zero (0) to three (3) lines

[LN ELPR(1) HORPR(1)...ELPR(NHORPR) HORPR(NHORPR)]

APPENDIX B: EXAMPLE SOLUTIONS FOR CANTILEVER WALLS

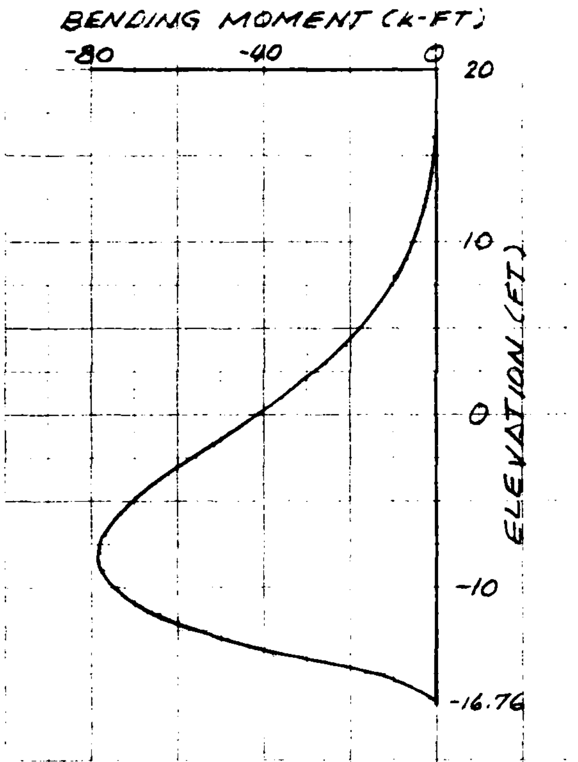
PROBLEM "CANT1"

Cantilever Retaining Wall Design--Granular Soil

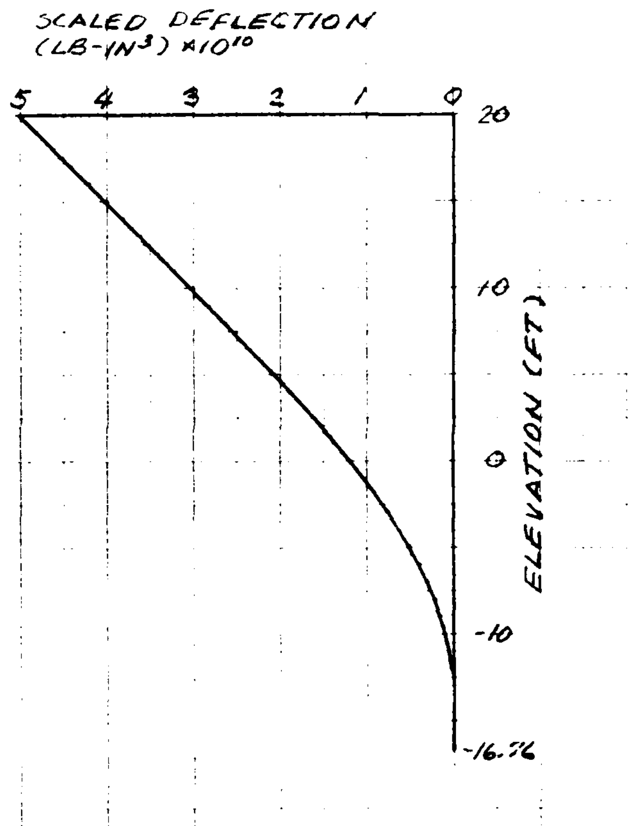


A. WALL AND SOIL   B. NET PRESSURE (PSF)

Figure B1. System and program results for problem "CANT1"



C. BENDING MOMENT



D. SCALED DEFLECTION

Figure B1. (Continued)

```
     PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
     OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
     DATE: 12/12/80                             TIME: 13:49:05


     ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
     ENTER 'TERMINAL' OR 'FILE'
I>FILE
     ENTER INPUT FILE NAME (6 CHARACTERS MAXIMUM)
I>CANT1
     INPUT COMPLETE. NO ERRORS DETECTED
     DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'
I>NO
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
     TERMINAL, TO A FILE, TO BOTH, OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'
I>T
```

```
1000 3 PROBLEM - CANT1 - CANTILEVER WALL DESIGN - GRANULAR SOIL
1010     FROM 'FOUNDATION ANALYSIS AND DESIGN' BY J. E. BOWLES
1020     EXAMPLE 13-2, PP 421-423
1030 C D
1040 20 1
1050 1 2
1060 20
1070 110 30 0 17 10 0
1080 122.5 30 0 17
1090 1 1
1100 0
1110 122.5 30 0 17
1120 10 10 62.5 1
1130 0 N
1140 0 0 0
```

PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 12/12/80 TIME: 13:49:54

1. INPUT DATA

1.A.--HEADING

PROBLEM - CANT1 - CANTILEVER WALL DESIGN - GRANULAR SOIL
FROM 'FOUNDATION ANALYSIS AND DESIGN' BY J. E. BOWLES
EXAMPLE 13-2, PP 421-423

1.B.--WALL TYPE, MODE, METHOD
CANTILEVER WALL DESIGN

1.C.--WALL DESCRIPTION
TOP OF WALL ELEVATION = 20.00 (FT)
FACTOR OF SAFETY = 1.00

1.D.--RIGHT SIDE SOIL DESCRIPTION
NUMBER OF RIGHT SIDE SURFACE POINTS = 1
NUMBER OF RIGHT SIDE SOIL LAYERS = 2

RIGHT SIDE SURFACE POINT COORDINATES

POINT NO.	ELEVATION (FT)	X-COORD (FT)
1	20.00	0.00

RIGHT SIDE SOIL LAYER DATA

LAYER NO.	UNIT WEIGHT (PCF)	INTERNAL FRICTION ANGLE (DEG)	COHESION (PSF)	WALL FRICTION ANGLE (DEG)	BOTTOM ELEV AT WALL (FT)	BOTTOM SLOPE (FT/FT)
1	110.00	30.00	0.00	17.00	10.00	1:0.0
2	122.50	30.00	0.00	17.00		

```
1.E.--LEFT SIDE SOIL DESCRIPTION
     NUMBER OF LEFT SIDE SURFACE POINTS    =  1
     NUMBER OF LEFT SIDE SOIL LAYERS       =  1


     LEFT SIDE SURFACE POINT COORDINATES
      POINT      ELEVATION      X-COORD
      NO.           (FT)          (FT)
       1            0.00          0.00
```

LEFT SIDE SOIL LAYER DATA

LAYER NO.	UNIT WEIGHT (PCF)	INTERNAL FRICTION ANGLE (DEG)	COHESION (PSF)	WALL FRICTION ANGLE (DEG)	BOTTOM ELEV AT WALL (FT)	BOTTOM SLOPE (FT/FT)
1	122.50	30.00	0.00	17.00		

```
1.F.--WATER DATA
      RIGHT SIDE ELEVATION          =   10.00 (FT)
     LEFT SIDE ELEVATION          =   10.00 (FT)
     WATER UNIT WEIGHT            =   62.50 (PCF)
     PRESSURE REDUCTION OPTION    =     1


1.G.--SURCHARGE LOADS
     NUMBER OF LINE LOADS             =  0
     DISTRIBUTED LOAD DISTRIBUTION = NONE


1.H.--HORIZONTAL LOADS
     NUMBER OF HORIZONTAL LINE LOADS           =     0
     NUMBER OF HORIZONTAL PRESSURE POINTS      =     0
     EARTHQUAKE ACCELERATION                   =     0.00 (G'S)

DO YOU WANT A PLOT OF INPUT GEOMETRY?
ENTER 'YES' OR 'NO'
I>N

INPUT SEQUENCE COMPLETE.
DO YOU WANT TO CONTINUE SOLUTION?
ENTER 'YES' OR 'NO'
I>Y
```

```
    DO YOU WANT ACTIVE AND PASSIVE SOIL PRESSURES
    PRINTED AT YOUR TERMINAL?  ENTER 'YES' OR 'NO'
I>Y
    ENTER ELEVATION (FT) BELOW     0.00 (FT)
    TO WHICH PRESSURES ARE DESIRED
I>-20
```

```
    PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
    OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
    DATE: 12/12/80                        TIME: 13:52:19

    HEADING

    PROBLEM - CANT1 - CANTILEVER WALL DESIGN - GRANULAR SOIL
    FROM 'FOUNDATION ANALYSIS AND DESIGN' BY J. E. BOWLES
    EXAMPLE 13-2, PP 421-423

    ACTIVE AND PASSIVE SOIL PRESSURES

         SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS.
          WATER PRESSURES AND PRESSURES DUE TO SURCHARGES ARE NOT INCLUDED.
```

ELEV	LEFT SIDE ACTIVE	LEFT SIDE PASSIVE	RIGHT SIDE ACTIVE	RIGHT SIDE PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)
20.00	0.00	0.00	0.00	0.00
19.00	0.00	0.00	32.94	592.35
18.00	0.00	0.00	65.88	1184.70
17.00	0.00	0.00	98.81	1777.05
16.00	0.00	0.00	131.75	2369.41
15.00	0.00	0.00	164.69	2961.76
14.00	0.00	0.00	197.63	3554.11
13.00	0.00	0.00	230.57	4146.46

12.00	0.00	0.00	263.51	4738.81
11.00	0.00	0.00	296.44	5331.16
10.00	0.00	0.00	329.38	5923.52
9.00	0.00	0.00	347.35	6246.62
8.00	0.00	0.00	365.31	6569.72
7.00	0.00	0.00	383.28	6892.82
6.00	0.00	0.00	401.25	7215.92
5.00	0.00	0.00	419.21	7539.02
4.00	0.00	0.00	437.18	7862.12
3.00	0.00	0.00	455.15	8185.22
2.00	0.00	0.00	473.11	8508.32
1.00	0.00	0.00	491.08	8831.42
0.00	0.00	0.00	509.05	9154.53
-1.00	17.97	323.10	527.01	9477.63
-2.00	35.93	646.20	544.98	9800.73
-3.00	53.90	969.30	562.94	10123.83
-4.00	71.87	1292.40	580.91	10446.93
-5.00	89.83	1615.50	598.88	10770.03
-6.00	107.80	1938.61	616.84	11093.13
-7.00	125.76	2261.71	634.81	11416.23
-8.00	143.73	2584.81	652.78	11739.33
-9.00	161.70	2907.91	670.74	12062.43
-10.00	179.66	3231.01	688.71	12385.53
-11.00	197.63	3554.11	706.67	12708.64
-12.00	215.60	3377.21	724.64	13031.74
-13.00	233.56	4200.31	742.61	13354.84
-14.00	251.53	4523.41	760.57	13677.94
-15.00	269.49	4346.51	778.54	14001.04
-16.00	287.46	5169.61	796.51	14324.14
-17.00	305.43	5492.72	814.47	14647.24
-18.00	323.39	5815.82	832.44	14970.34
-19.00	341.36	6138.92	850.41	15293.44
-20.00	359.33	6462.02	868.37	15616.54

```
    SOLUTION COMPLETE
    DO YOU WANT RESULTS PRINTED AT YOUR TERMINAL,
    WRITTEN TO A FILE, OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'
I>T
```

```
PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 12/12/80                         TIME: 13:55:01

2. RESULTS

2.A.--HEADING

PROBLEM - CANT1 - CANTILEVER WALL DESIGN - GRANULAR SOIL
FROM 'FOUNDATION ANALYSIS AND DESIGN' BY J. E. BOWLES
EXAMPLE 13-2, PP 421-423


2.B.--SUMMARY OF RESULTS FOR CANTILEVER WALL DESIGN


      SOIL PRESSURES DETERMINED BY COULOMB
     COEFFICIENTS AND THEORY OF ELASTICITY
     EQUATIONS FOR SURCHARGE LOADS


     WALL BOTTOM:
          PENETRATION =      16.8 (FT)
          ELEVATION   =     -16.8 (FT)


     BENDING MOMENT:
          MAXIMUM     =   -78392. (LB-FT)
          ELEVATION   =      -8.1 (FT)


     SCALED DEFLECTION:
          MAXIMUM     =  5.00E+10 (LB-IN3)
          ELEVATION   =      20.0 (FT)


            (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
          OF ELASTICITY IN PSI TIMES PILE MOMENT OF
          INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)


DO YOU WANT COMPLETE RESULTS OUTPUT?
ENTER 'YES' OR 'NO'
I>Y
```

2.C.--COMPLETE RESULTS FOR CANTILEVER WALL DESIGN

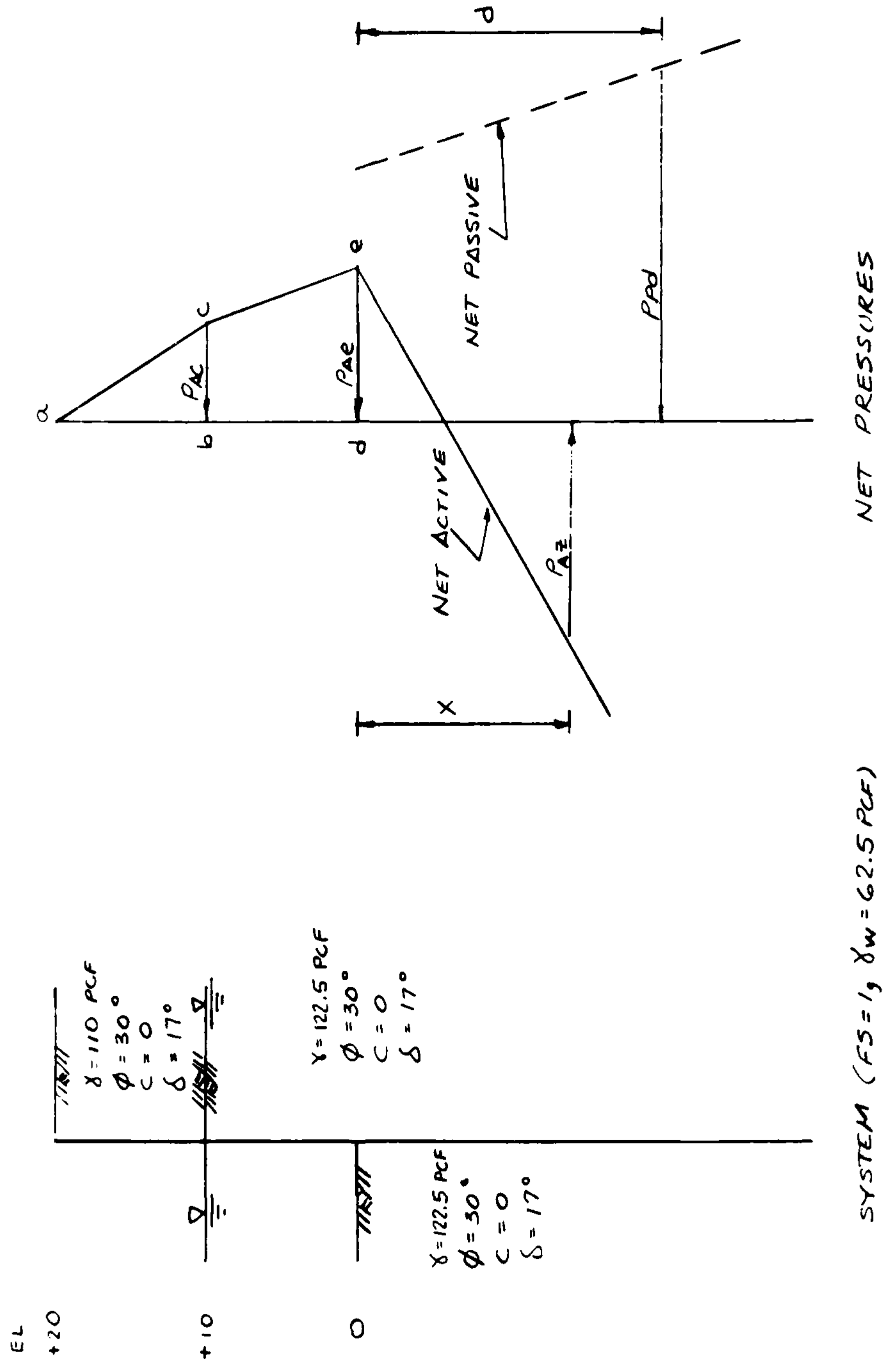
ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	-0.	0.	5.00E+10	0.00
19.00	-5.	-16.	4.80E+10	32.94
18.00	-44.	-66.	4.61E+10	65.88
17.00	-148.	-148.	4.41E+10	98.81
16.00	-351.	-264.	4.21E+10	131.75
15.00	-686.	-412.	4.01E+10	164.69
14.00	-1186.	-593.	3.81E+10	197.63
13.00	-1883.	-807.	3.62E+10	230.57
12.00	-2811.	-1054.	3.42E+10	263.51
11.00	-4002.	-1334.	3.22E+10	296.44
10.00	-5490.	-1647.	3.03E+10	329.38
9.00	-7304.	-1985.	2.83E+10	347.35
8.00	-9466.	-2342.	2.64E+10	365.31
7.00	-11994.	-2715.	2.45E+10	383.28
6.00	-14904.	-3108.	2.26E+10	401.25
5.00	-18216.	-3518.	2.07E+10	419.21
4.00	-21947.	-3947.	1.88E+10	437.18
3.00	-26115.	-4393.	1.70E+10	455.15
2.00	-30738.	-4857.	1.53E+10	473.11
1.00	-35835.	-5339.	1.36E+10	491.08
0.00	-41422.	-5839.	1.19E+10	509.05
-1.00	-47465.	-6196.	1.04E+10	203.91
-1.67	-51636.	-6264.	9.34E+09	0.00
-3.00	-59857.	-5993.	7.46E+09	-406.36

-4.00	-65596.	-5434.	6.17E+09	-711.49
-5.00	-70624.	-4570.	4.98E+09	-1016.63
-6.00	-74635.	-3401.	3.92E+09	-1321.76
-7.00	-77324.	-1927.	2.99E+09	-1626.90
-8.00	-78386.	-147.	2.19E+09	-1932.03
-9.00	-77516.	1937.	1.53E+09	-2237.17
-10.00	-74409.	4327.	1.00E+09	-2542.30
-11.00	-68760.	7022.	6.02E+08	-2847.43
-12.00	-60263.	10022.	3.20E+08	-3152.57
-13.00	-48614.	13327.	1.41E+08	-3457.70
-13.74	-37752.	15977.	6.39E+07	-3684.14
-14.36	-27382.	17118.	2.72E+07	0.00
-15.74	-6358.	11452.	1.01E+06	8209.62
-16.76	-0.	-0.	0.	14268.88

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

```
    DO YOU WANT GEOMETRY AND/OR RESULTS PLOTTED?
    ENTER 'GEOMETRY', 'RESULTS', 'BOTH', OR 'NEITHER'
I>N
    OUTPUT COMPLETE
    DO YOU WANT TO EDIT INPUT DATA FOR THE
    PROBLEM JUST COMPLETED?  ENTER 'YES' OR 'NO'
I>N
    DO YOU WANT TO MAKE ANOTHER RUN?  ENTER 'YES' OR 'NO'
I>N
          **********  NORMAL TERMINATION  **********
```

Verification of Problem "CANT1" (Sheet 1 of 6)



PRESSURE COEFFICIENTS:

$$K_A = \left[\frac{\cos\phi}{1+\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi-\beta)}{\cos\delta\ \cos\beta}}}\right]^2 \frac{1}{\cos\delta}$$

$$= \left[\frac{\cos(30)}{1+\sqrt{\dfrac{\sin(47)\sin(30)}{\cos(17)\ \cos(0)}}}\right]^2 \frac{1}{\cos(17)} = 0.2994$$

$$K_P = \left[\frac{\cos\phi}{1-\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi-\beta)}{\cos\delta\ \cos\beta}}}\right]^2 \frac{1}{\cos\delta}$$

$$= \left[\frac{\cos(30)}{1-\sqrt{\dfrac{\sin(47)\sin(30)}{\cos(17)\ \cos(0)}}}\right]^2 \frac{1}{\cos(17)} = 5.3850$$

PRESSURE VALUES:

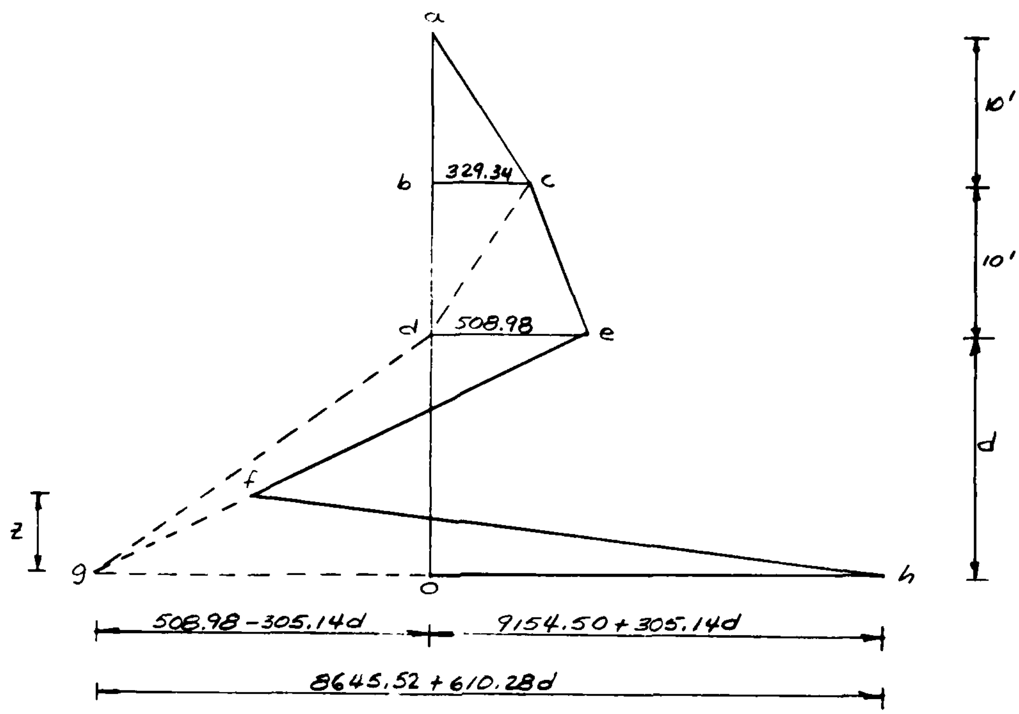
$P_{AC} = (110\ PCF)(10\ FT)(K_A) = 329.34\ PSF$

$P_{AC} = [(110\ PCF)(10\ FT) + (122.5\ PCF - 62.5\ PCF)(10\ FT)](K_A) = 508.98\ PSF$

$P_{Az} = [(110\ PCF)(10\ FT) + 60\ PCF\ (10+x)](K_A)$
$\quad - (60\ PCF)(x)(K_P) = 508.98\ PSF - 305.14(x)$

$P_{Pd} = [(110\ PCF)(10\ FT) + 60\ PCF\ (10+d)](K_P)$
$\quad - (60\ PCF)(d)(K_A) = 9154.50\ PSF + 305.14(d)$

NET PRESSURE DIAGRAM FOR DESIGN



FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	abc	329.34(10)/2 = 1646.70	d + 13.33	21950.51 + 1646.70d
P2	bcd	329.34 (10)/2 = 1646.70	d + 6.67	10983.49 + 1646.70d
P3	cde	508.98 (10)/2 = 2544.90	d + 3.33	8474.52 + 2544.90d
P4	deg	508.98 (d)/2 = 254.49d	0.67d	$170.51d^2$
P5	dog	(508.98 - 305.14d)(d)/2 = $254.49d - 152.57d^2$	0.33d	$83.98d^2 - 50.35d^3$
P6	fgh	(8645.52 + 610.28d)(z)/2 = (4322.76 + 305.14d)z	0.33z	(1426.51 + 100.70d)z

$\Sigma F_H = \Sigma F = 5838.30 + 508.98d - 152.57d^2 + (4322.76 + 305.14d)z$

$\Sigma M_o = 41408.52 + 5838.30d + 254.49d^2 - 50.35d^3$
$+ (1426.51 + 100.70d)z^2$

FOR $\Sigma F_H = 0$ $\quad z = \dfrac{152.57d^2 - 508.98d - 5838.30}{4322.76 + 305.14d}$

PROCEDURE:
1. ASSUME d
2. CALCULATE z FOR $\Sigma F_H = 0$
3. CHECK $\Sigma M_o = 0$

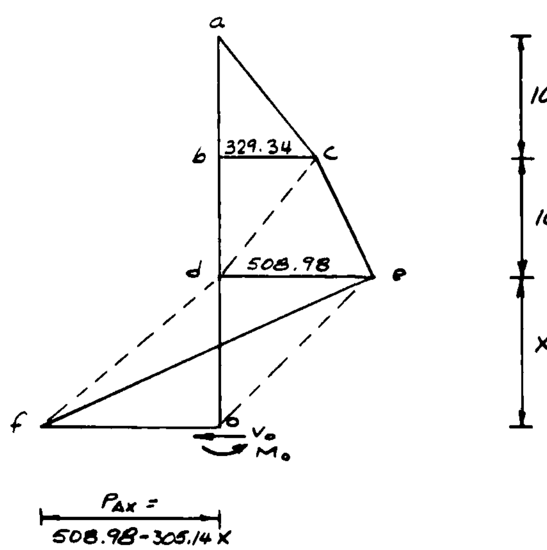
TRIAL d	z	ΣM_o	
15'	2.34	32394	NG
16'	2.72	16211	NG
17'	3.11	-2807	

INTERPOLATE $d = 16 + 16211/(16211 + 2807) = 16.85'$

16.85'	3.05	215	SAY OK

(PROGRAM 16.76')
(BOWLES 16.65')

DETERMINE MAXIMUM BENDING MOMENT:



FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	abc	1646.70	$x + 13.33$	$21950.51 + 1646.70x$
P2	bcd	1646.70	$x + 6.67$	$10983.49 + 1646.70x$
P3	cde	2544.90	$x + 3.33$	$8474.52 + 2544.90x$
P4	deo	$508.98(x)/2 = 254.49x$	$0.67x$	$170.51x^2$
P5	afo	$(508.98 - 305.14x)(x)/2 = 254.49x - 152.57x^2$	$0.33x$	$83.98x^2 + -50.35x^3$

$$V_o = \Sigma P = 5838.30 + 508.98x - 152.57x^2$$

$$M_o = -\left[41408.52 + 5838.30x + 254.49x^2 - 50.35x^3\right]$$

FOR MAXIMUM M_o, $V_o = 0$ AT

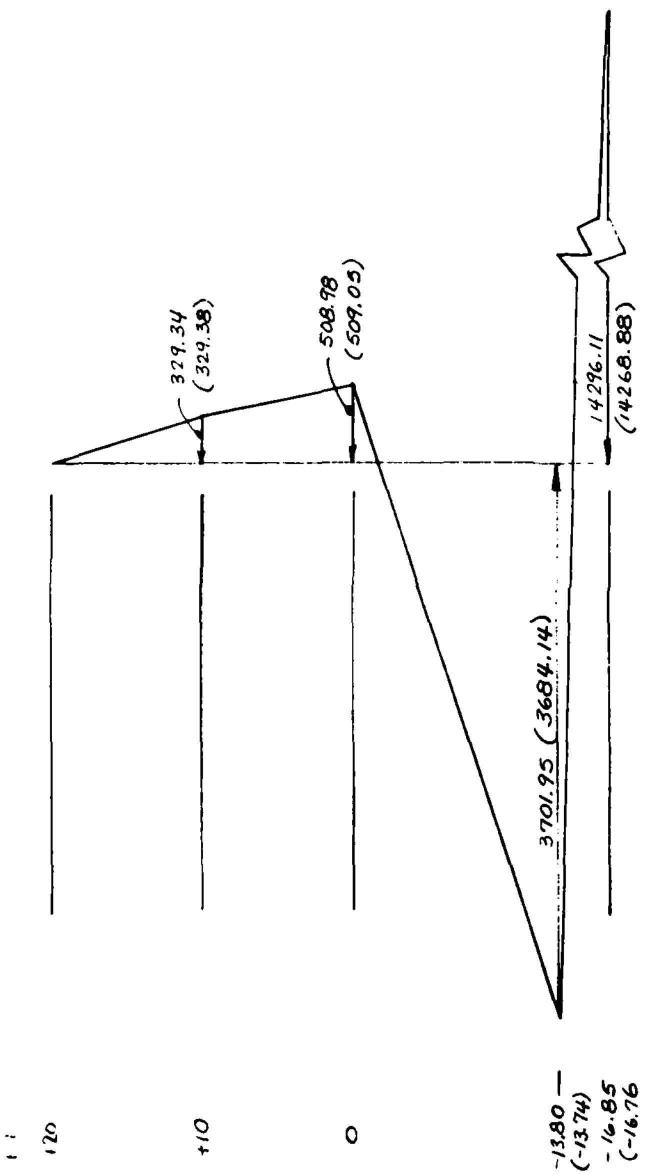
$$x = \frac{-508.98 \pm \sqrt{(508.98)^2 - 4(-152.57)(5838.30)}}{2(-152.57)}$$

$x = 8.07'$ (PROGRAM $8.1'$)

$M_{MAX} = -78635$ LB-FT (PROGRAM -78392 LB-FT)

Verification of Problem "CANT1" (Sheet 6 of 6)

FINAL NET DIAGRAM (PROGRAM VALUES IN PARENTHESES)



PROBLEM "CANT1A"

Analysis of Wall of Problem "CANT1"
for Bottom of Wall at EL -16.76

```
    PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
    OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
    DATE: 12/12/80                               TIME: 14:15:46


    ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
    ENTER 'TERMINAL' OR 'FILE'
I>F
    ENTER INPUT FILE NAME (6 CHARACTERS MAXIMUM)
I>CANT1
    INPUT COMPLETE. NO ERRORS DETECTED
    DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'
I>Y
    DO YOU WANT A LISTING OF CURRENT INPUT DATA?
    ENTER 'YES' OR 'NO'
I>N
    FOLLOWING ARE IDENTIFIERS FOR SECTIONS OF INPUT DATA:
         SECTION ID            SECTION CONTENTS
             A                 HEADING
             B                 WALL TYPE,MODE,METHOD
             C                 WALL DESCRIPTION
             D                 RIGHT SIDE SOIL DESCRIPTION
             E                 LEFT SIDE SOIL DESCRIPTION
             F                 WATER DATA
             G                 SURCHARGE LOAD DATA
             H                 HORIZONTAL LOAD DATA


    ENTER ID FOR DATA SECTION TO BE CHANGED
I>A

    ENTER NUMBER OF HEADER LINES (1 TO 4)
I>2

    ENTER FIRST  HEADER LINE (1 TO 70 CHARACTERS)
I>PROBLEM - CANT1A - SAME AS PROBLEM CANT1 EXCEPT

    ENTER SECOND HEADER LINE (1 TO 70 CHARACTERS)
I>ANALYZE FOR BOTTOM OF WALL AT EL -16.76
```

```
       DO YOU WANT TO CHANGE ANOTHER SECTION?  ENTER 'YES' OR 'NO'
I>Y
       ENTER ID FOR DATA SECTION TO BE CHANGED
I>B
       ENTER WALL TYPE: 'CANT' OR 'ANCH'
I>C
       ENTER MODE: 'DESIGN' OR 'ANALYSIS'
I>A
       CHANGE IN    MODE   ALSO REQUIRES CHANGE IN WALL DESCRIPTION

       WALL DATA, ENTER VALUES UNDER HEADINGS




            ELEVATION AT          MODULUS         MOMENT
          TOP OF    BOTTOM           OF             OF
           WALL     OF WALL      ELASTICITY       INERTIA
           (FT)      (FT)          (PSI)          (IN**4)
I>         20.0     -16.76       29.0E06          220.4
       DO YOU WANT TO CHANGE ANOTHER SECTION?  ENTER 'YES' OR 'NO'
I>N
       DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
       TERMINAL, TO A FILE, TO BOTH, OR NEITHER?
       ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'
I>T
```

PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 12/12/80 TIME: 14:19:58

1. INPUT DATA

1.A.--HEADING

PROBLEM - CANT1A - SAME AS PROBLEM CANT1 EXCEPT
ANALYZE FOR BOTTOM OF WALL AT EL -16.76

1.B.--WALL TYPE, MODE, METHOD
CANTILEVER WALL ANALYSIS

1.C.--WALL DESCRIPTION

TOP OF WALL ELEVATION	= 20.00 (FT)
BOTTOM OF WALL ELEVATION	= -16.76 (FT)
MODULUS OF ELASTICITY	= 2.900E+07 (PSI)
MOMENT OF INERTIA	= 2.204E+02 (IN**4)

1.D.--RIGHT SIDE SOIL DESCRIPTION

NUMBER OF RIGHT SIDE SURFACE POINTS	= 1
NUMBER OF RIGHT SIDE SOIL LAYERS	= 2

RIGHT SIDE SURFACE POINT COORDINATES

POINT NO.	ELEVATION (FT)	X-COORD (FT)
1	20.00	0.00

RIGHT SIDE SOIL LAYER DATA

LAYER NO.	UNIT WEIGHT (PCF)	INTERNAL FRICTION ANGLE (DEG)	COHESION (PSF)	WALL FRICTION ANGLE (DEG)	BOTTOM ELEV AT WALL (FT)	BOTTOM SLOPE (FT/FT)
1	110.00	30.00	0.00	17.00	10.00	1:0.0
2	122.50	30.00	0.00	17.00		

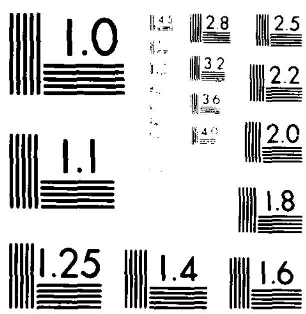
```
1.E.--LEFT SIDE SOIL DESCRIPTION
     NUMBER OF LEFT SIDE SURFACE POINTS     =  1
     NUMBER OF LEFT SIDE SOIL LAYERS        =  1

      LEFT SIDE SURFACE POINT COORDINATES
     POINT       ELEVATION      X-COORD
      NO.          (FT)          (FT)
       1            0.00          0.00

LEFT  SIDE SOIL LAYER DATA
                INTERNAL                WALL      BOTTOM

LAYER    UNIT   FRICTION                FRICTION    ELEV        BOTTOM
 NO.    WEIGHT   ANGLE     COHESION     ANGLE     AT WALL       SLOPE
        (PCF)    (DEG)      (PSF)       (DEG)      (FT)        (FT/FT)
  1     122.50   30.00      0.00        17.00

 1.F.--WATER DATA
     RIGHT SIDE ELEVATION          =   10.00 (FT)
     LEFT SIDE ELEVATION           =   10.00 (FT)
     WATER UNIT WEIGHT             =   62.50 (PCF)
     PRESSURE REDUCTION OPTION     =    1

1.G.--SURCHARGE LOADS
     NUMBER OF LINE LOADS            =  0
     DISTRIBUTED LOAD DISTRIBUTION = NONE

1.H.--HORIZONTAL LOADS
     NUMBER OF HORIZONTAL LINE LOADS          =    0
     NUMBER OF HORIZONTAL PRESSURE POINTS     =    0
      EARTHQUAKE ACCELERATION                  =    0.00 (G'S)


    DO YOU WANT INPUT DATA SAVED IN A FILE? ENTER 'YES' OR 'NO'
I>N
    DO YOU WANT A PLOT OF INPUT GEOMETRY?
    ENTER 'YES' OR 'NO'
I>N


    INPUT SEQUENCE COMPLETE.
    DO YOU WANT TO CONTINUE SOLUTION?
    ENTER 'YES' OR 'NO'
I>Y
```

AD-A098 693 OKLAHOMA STATE UNIV STILLWATER DEPT OF CIVIL ENGINEERING F/G 13/13
USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET--ETC(U)
FEB 81 W P DAWKINS DACW39-79-M-1229

UNCLASSIFIED WES-INSTRUCTION-K-81-2-1 NL

2 OF 3

AD
A098693



MICROCOPY RESOLUTION TEST CHART

```
    SOLUTION COMPLETE
    DO YOU WANT RESULTS PRINTED AT YOUR TERMINAL,
    WRITTEN TO A FILE, OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'
I>T


    PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
    OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
    DATE: 12/12/80                          TIME: 14:23:23

    2. RESULTS

    2.A.--HEADING

    PROBLEM - CANT1A - SAME AS PROBLEM CANT1 EXCEPT
    ANALYZE FOR BOTTOM OF WALL AT EL -16.76



    2.B.--SUMMARY OF RESULTS FOR CANTILEVER WALL ANALYSIS

          SOIL PRESSURES DETERMINED BY COULOMB
           COEFFICIENTS AND THEORY OF ELASTICITY
          EQUATIONS FOR SURCHARGE LOADS


          FACTOR OF SAFETY = 1.00

          BENDING MOMENT:
               MAXIMUM      =   -78392. (LB-FT)
               ELEVATION    =       -8.1 (FT)

          DEFLECTION:
               MAXIMUM      =  7.83E+00 (IN)
               ELEVATION    =       20.0 (FT)

    DO YOU WANT COMPLETE RESULTS OUTPUT?
    ENTER 'YES' OR 'NO'
I>Y
```

2.C.--COMPLETE RESULTS FOR CANTILEVER WALL ANALYSIS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (IN)	NET PRESSURE (PSF)
20.00	0.	0.	7.83E+00	0.00
19.00	-5.	-16.	7.52E+00	32.94
18.00	-44.	-66.	7.21E+00	65.88
17.00	-148.	-148.	6.90E+00	98.81
16.00	-351.	-264.	6.59E+00	131.75
15.00	-686.	-412.	6.28E+00	164.69
14.00	-1186.	-593.	5.97E+00	197.63
13.00	-1883.	-807.	5.66E+00	230.57
12.00	-2811.	-1054.	5.35E+00	263.51
11.00	-4002.	-1334.	5.04E+00	296.44
10.00	-5490.	-1647.	4.74E+00	329.38
9.00	-7304.	-1985.	4.43E+00	347.35
8.00	-9466.	-2342.	4.13E+00	365.31
7.00	-11994.	-2716.	3.83E+00	383.28
6.00	-14904.	-3108.	3.53E+00	401.25
5.00	-18216.	-3518.	3.24E+00	419.21
4.00	-21947.	-3947.	2.95E+00	437.18
3.00	-26115.	-4393.	2.67E+00	455.15
2.00	-30738.	-4857.	2.39E+00	473.11
1.00	-35835.	-5339.	2.12E+00	491.08
0.00	-41422.	-5839.	1.87E+00	509.05
-1.00	-47465.	-6196.	1.62E+00	203.91
-1.67	-51636.	-6264.	1.46E+00	0.00
-3.00	-59857.	-5993.	1.17E+00	-406.36
-4.00	-65596.	-5434.	9.65E-01	-711.49
-5.00	-70624.	-4570.	7.80E-01	-1016.63
-6.00	-74635.	-3401.	6.14E-01	-1321.76
-7.00	-77324.	-1927.	4.68E-01	-1626.90
-8.00	-78386.	-147.	3.43E-01	-1932.03
-9.00	-77516.	1937.	2.40E-01	-2237.17
-10.00	-74409.	4327.	1.57E-01	-2542.30
-11.00	-68760.	7022.	9.42E-02	-2847.43
-12.00	-60263.	10022.	5.00E-02	-3152.57
-13.00	-48614.	13327.	2.21E-02	-3457.70
-13.74	-37752.	15977.	9.99E-03	-3684.14
-14.36	-27382.	17118.	4.26E-03	0.00
-15.74	-6358.	11452.	1.59E-04	8209.62
-16.76	-0.	-0.	0.	14268.88

PROBLEM "CANT2"

Cantilever Floodwall Design--Cohesive Soil

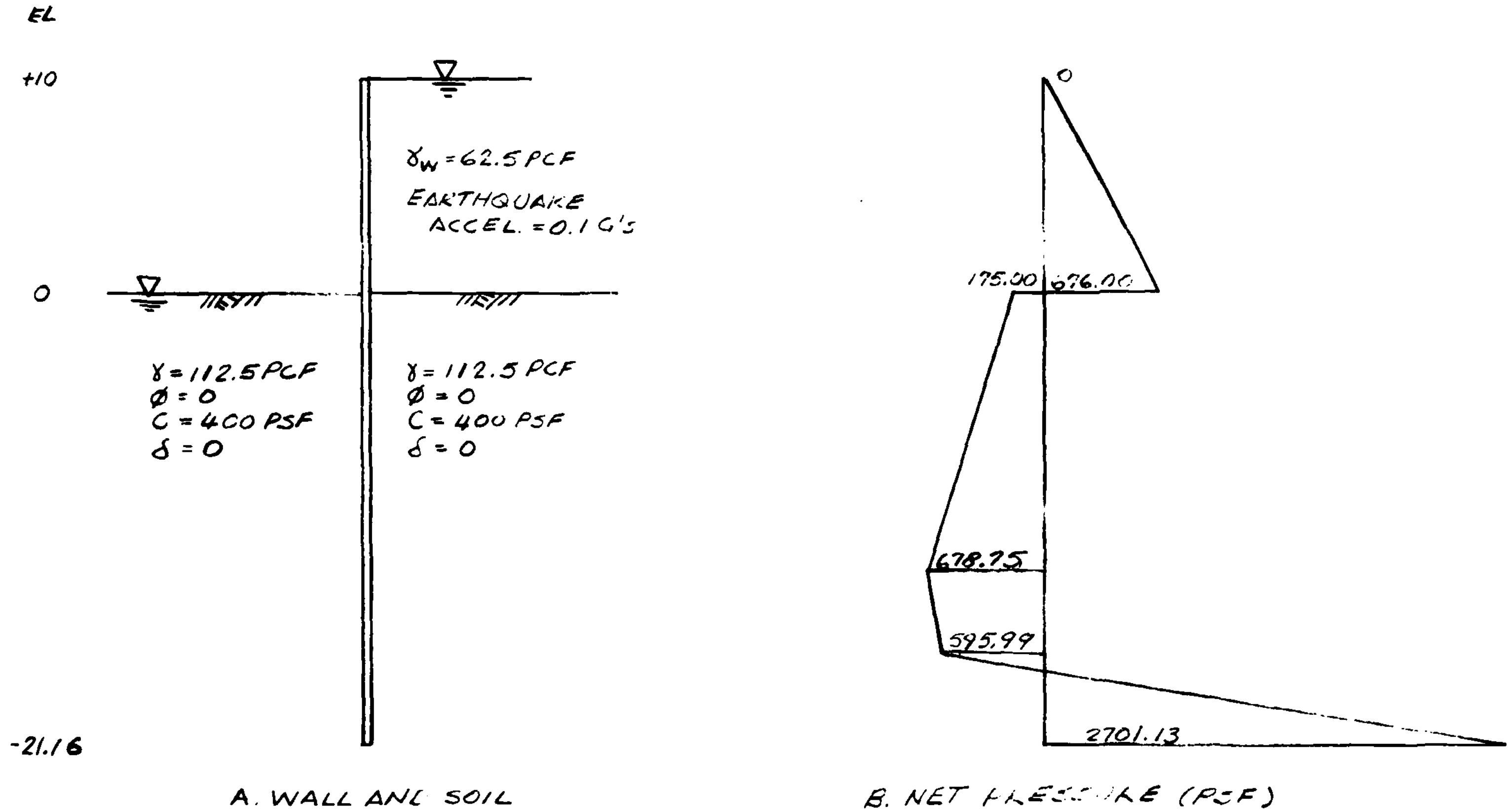


Figure B2. System and program results for problem "CANT2"

```
    PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
    OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
    DATE: 12/12/80                       TIME: 14:31:16

    ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
    ENTER 'TERMINAL' OR 'FILE'
I>TERM

    ENTER NUMBER OF HEADER LINES (1 TO 4)
I>3

    ENTER FIRST  HEADER LINE (1 TO 70 CHARACTERS)
I>    PROBLEM - CANT2 - CANTILEVER WALL DESIGN

    ENTER SECOND HEADER LINE (1 TO 70 CHARACTERS)
I>    FLOODWALL - COHESIVE SOIL

    ENTER THIRD  HEADER LINE (1 TO 70 CHARACTERS)
I>    EARTHQUAKE ACCELERATION = 0.1 G'S

    ENTER WALL TYPE: 'CANT' OR 'ANCH'
I>C

    ENTER MODE: 'DESIGN' OR 'ANALYSIS'
I>D

    WALL DATA, ENTER VALUES UNDER HEADINGS

      ELEVATION AT           FACTOR
         TOP OF                OF
          WALL               SAFETY
          (FT)
I>         10                   1
```

RIGHT SIDE SOIL DESCRIPTION. ENTER

```
       NUMBER OF          NUMBER OF
     SURFACE POINTS      SOIL LAYERS
       (1 TO 15)          (1 TO 15)
I>         1                  1
```

ENTER 1 SURFACE POINT ELEVATIONS UNDER HEADINGS

```
     SUREL( 1)  SUREL(
       (FT)        (FT)        (FT)        (FT)        (FT)
I>     0
```

ENTER SOIL LAYER DATA UNDER HEADINGS. ONE LINE PER LAYER

```
     SATURATED  INTERNAL                 WALL     BOTTOM
       UNIT     FRICTION               FRICTION    ELEV       BOTTOM
      WEIGHT     ANGLE     COHESION     ANGLE     AT WALL     SLOPE
      (PCF)      (DEG)      (PSF)       (DEG)      (FT)       (FT/FT)
I>    112.5        0         400          0
```

LEFT SIDE SOIL DESCRIPTION. ENTER

```
       NUMBER OF          NUMBER OF
     SURFACE POINTS      SOIL LAYERS
       (1 TO 15)          (1 TO 15)
I>         1                  1
```

ENTER 1 SURFACE POINT ELEVATIONS UNDER HEADINGS

```
     SUREL( 1)  SUREL(
       (FT)        (FT)        (FT)        (FT)        (FT)
I>     0
```

ENTER SOIL LAYER DATA UNDER HEADINGS. ONE LINE PER LAYER

```
     SATURATED  INTERNAL                 WALL     BOTTOM
       UNIT     FRICTION               FRICTION    ELEV       BOTTOM
      WEIGHT     ANGLE     COHESION     ANGLE     AT WALL     SLOPE
      (PCF)      (DEG)      (PSF)       (DEG)      (FT)       (FT/FT)
I>     112.5       0         400          0
```

```
    WATER DATA, ENTER VALUES UNDER HEADINGS

    RIGHT SIDE      LEFT SIDE       UNIT       PRESSURE
    ELEVATION       ELEVATION      WEIGHT       OPTION
      (FT)            (FT)          (PCF)      (0 OR 1)
I>     10              0            62.5           1

    SURCHARGE LOADS ON RIGHT SIDE SURFACE

    ENTER NUMBER OF LINE LOADS (0 TO 4)
I>0

    DISTRIBUTED LOAD DESCRIPTION
    ENTER 'NONE', 'STRIP', 'RAMP', 'TRIANG', OR 'UNIF'
I>NONE

    HORIZONTAL LOAD DATA. ENTER
    NUMBER OF       NUMBER OF       EARTHQUAKE
    LINE LOADS    PRESSURE PTS    ACCELERATION
     (0 TO 4)    (0 OR 2 TO 12)       (G'S)
I>     0               0               0.1
    INPUT COMPLETE. NO ERRORS DETECTED
    DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'
I>N
    DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
    TERMINAL, TO A FILE, TO BOTH, OR NEITHER?
    ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'
I>N
    DO YOU WANT INPUT DATA SAVED IN A FILE? ENTER 'YES' OR 'NO'
I>Y
    ENTER FILE NAME IN WHICH INPUT DATA WILL BE SAVED.
     (6 CHARACTERS MAXIMUM)
I>CANT2
    DO YOU WANT A PLOT OF INPUT GEOMETRY?
    ENTER 'YES' OR 'NO'
I>N
    INPUT SEQUENCE COMPLETE.
    DO YOU WANT TO CONTINUE SOLUTION?
    ENTER 'YES' OR 'NO'
I>Y
```

```
    DO YOU WANT ACTIVE AND PASSIVE SOIL PRESSURES
    PRINTED AT YOUR TERMINAL?  ENTER 'YES' OR 'NO'
I>N
    SOLUTION COMPLETE
    DO YOU WANT RESULTS PRINTED AT YOUR TERMINAL,
    WRITTEN TO A FILE, OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'
I>T
    PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
    OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
    DATE: 12/12/80

RESA B29




**********************************************************************
FOLLOWING IS FILE - CANT2 CREATED BY PROGRAM
1000 3     PROBLEM - CANT2 - CANTILEVER WALL DESIGN
1010     FLOODWALL - COHESIVE SOIL
1020     EARTHQUAKE ACCELERATION = 0.1 G'S
1030 C D
1040 10. 1.
1050 1 1
1060 0.
1070 112.5 0. 400. 0.
1080 1 1
1090 0.
1100 112.5 0. 400. 0.
1110 10. 0. 62.5 1
1120 0 N
1130 0 0 .1
```

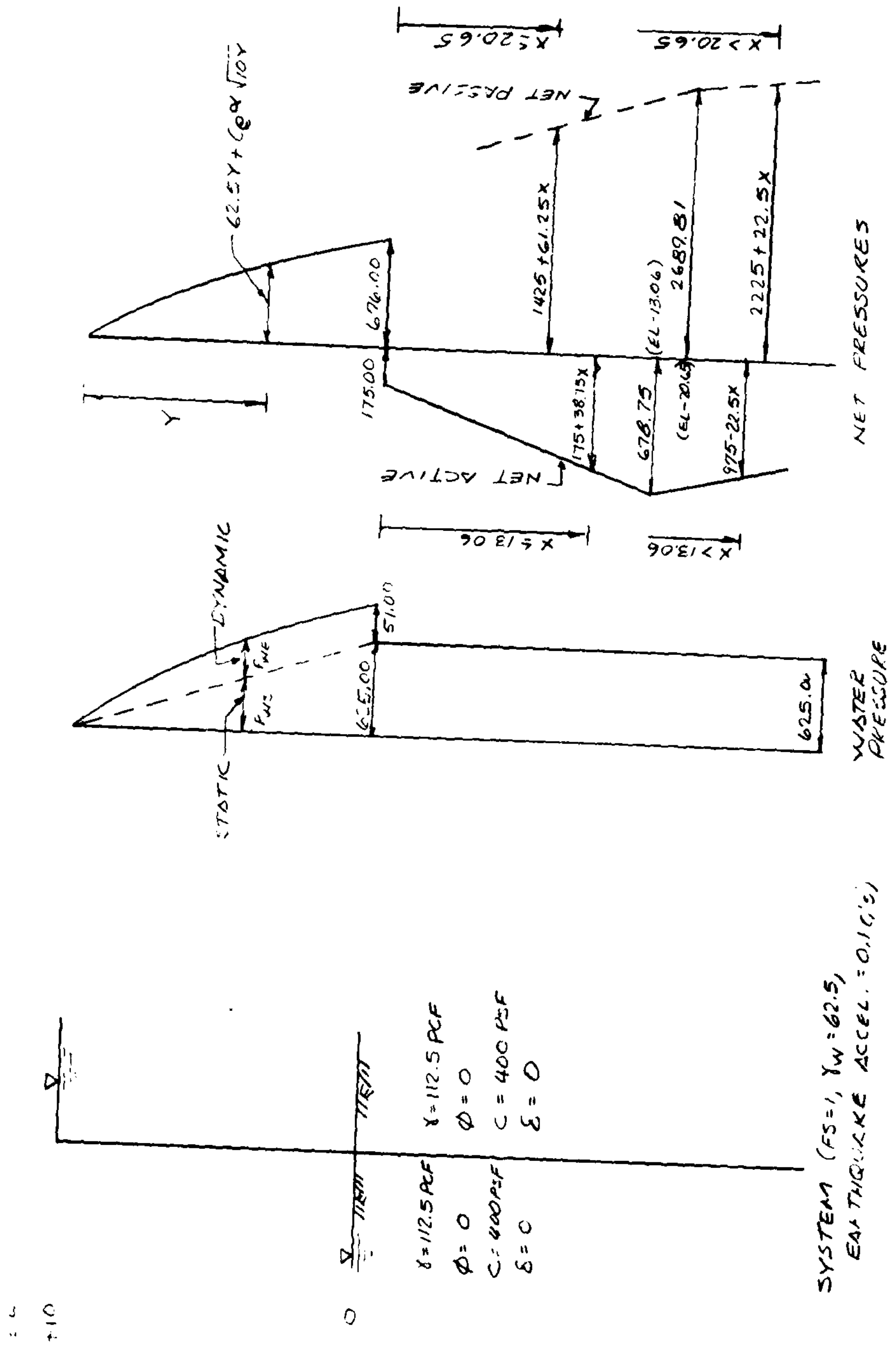
```
PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 12/12/80                              TIME: 14:38:27

2. RESULTS

2.A.--HEADING

    PROBLEM - CANT2 - CANTILEVER WALL DESIGN
    FLOODWALL - COHESIVE SOIL
    EARTHQUAKE ACCELERATION = 0.1 G'S


2.B.--SUMMARY OF RESULTS FOR CANTILEVER WALL DESIGN


      SOIL PRESSURES DETERMINED BY COULOMB
     COEFFICIENTS AND THEORY OF ELASTICITY
     EQUATIONS FOR SURCHARGE LOADS


     WALL BOTTOM:
          PENETRATION =      21.2 (FT)
          ELEVATION   =     -21.2 (FT)

     BENDING MOMENT:
          MAXIMUM     =   -31204. (LB-FT)
          ELEVATION   =      -9.6 (FT)

     SCALED DEFLECTION:
          MAXIMUM     =  1.52E+10 (LB-IN3)
          ELEVATION   =      10.0 (FT)

           (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
          OF ELASTICITY IN PSI TIMES PILE MOMENT OF
          INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)


    DO YOU WANT COMPLETE RESULTS OUTPUT?
    ENTER 'YES' OR 'NO'
I>Y
```

2.C.--COMPLETE RESULTS FOR CANTILEVER WALL DESIGN

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
10.00	-0.	0.	1.52E+10	0.00
9.00	-13.	-39.	1.44E+10	78.63
8.00	-103.	-153.	1.36E+10	147.81
7.00	-341.	-334.	1.28E+10	215.43
6.00	-794.	-583.	1.20E+10	282.26
5.00	-1529.	-898.	1.11E+10	348.56
4.00	-2613.	-1280.	1.03E+10	414.51
3.00	-4111.	-1727.	9.52E+09	480.17
2.00	-6089.	-2240.	8.71E+09	545.62
1.00	-8613.	-2818.	7.92E+09	610.88
0.00	-11748.	-3462	7.14E+09	676.00
0.00	-11748.	-3462.	7.14E+09	-175.00
-1.00	-15116.	-3267.	6.38E+09	-213.75
-2.00	-18270.	-3034.	5.65E+09	-252.50
-3.00	-21172.	-2762.	4.95E+09	-291.25
-4.00	-23782.	-2452.	4.28E+09	-330.00
-5.00	-26062.	-2102.	3.66E+09	-368.75
-6.00	-27974.	-1714.	3.08E+09	-407.50
-7.00	-29478.	-1287.	2.55E+09	-446.25
-8.00	-30536.	-822.	2.07E+09	-485.00
-9.00	-31109.	-317.	1.65E+09	-523.75
-9.59	-31204.	0.	1.43E+09	-546.74
-10.00	-31158.	226.	1.27E+09	-562.50
-11.00	-30645.	808.	9.55E+08	-601.25
-12.00	-29530.	1428.	6.89E+08	-640.00
-13.00	-27776.	2088.	4.74E+08	-678.75
-14.00	-25352.	2757.	3.06E+08	-660.00
-15.00	-22269.	3406.	1.83E+08	-637.50
-16.00	-18548.	4032.	9.77E+07	-615.00
-16.84	-14925.	4543.	5.10E+07	-595.99
-17.63	-11259.	4776.	2.43E+07	0.00
-18.84	-5665.	4208.	4.87E+06	931.70
-19.84	-2050.	2894.	5.41E+05	1695.54
-20.84	-131.	817.	1.92E+03	2459.39
-21.16	-0.	0.	0.	2701.13

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES

Verification of Problem "CANT2" (Sheet 1 of 5)



PRESSURE CALCULATIONS:

EARTHQUAKE WATER PRESSURE:

AT Y BELOW RIGHT SIDE WATER SURFACE

$P_{WS} = 62.5Y$

$P_{WE} = C_e \alpha \sqrt{HY}$, $H = 10'$, $\alpha = 0.1$

$C_e = 51 \Big/ \sqrt{1 - 0.72\,(H/1000)^2} = 51.0018$

$P_{WE} = 51.0018\,(0.1)\sqrt{10Y} = 5.10018\sqrt{10Y}$

AT EL 0 $(Y = 10')$ $P_{WE} = 51.00$ PSF

TOTAL AT $Y = P_W = P_{WS} + P_{WE} = 62.5Y + 5.10018\sqrt{10Y}$
BELOW RIGHT SIDE SURFACE $P_W = 625.00$

RESULTANT OF $P_{WE} = \frac{2}{3} C_e \alpha H^2 = \frac{2}{3}(51.0018)(0.1)(10)^2 = 340.01$#

LOCATION OF RESULTANT OF P_{WE} AT $2/5\,H = 4'$ ABOVE EL 0.

RIGHT SIDE SOIL ACTIVE PRESSURE:

EFFECTIVE SOIL WEIGHT, $\gamma_E = \gamma(1+\alpha) - \gamma_W$
$= 112.5(1+0.1) - 62.5 = 61.25$ PCF

NEGATIVE ACTIVE PRESSURE SET TO ZERO
TO DEPTH $= 2C/\gamma_E = 2(400)/61.25 = 13.06'$

AT X BELOW RIGHT SIDE SURFACE $(X > 13.06')$
$P_{AR} = \gamma_E X - 2C = 61.25X - 800$

LEFT SIDE SOIL PASSIVE PRESSURE:

EFFECTIVE SOIL WEIGHT, $\gamma_E = \gamma(1-\alpha) - \gamma_W = 38.75$ PCF

AT X BELOW LEFT SIDE SURFACE
$P_{PL} = \gamma_E X + 2C = 38.75X + 800$

NET ACTIVE PRESSURE: $P_{ANET} = P_{AR} - P_{PL} + P_W$

$0 \le X \le 13.06$: $P_{ANET} = 0 - [38.75X + 800] + 625.00$
$= -[175.00 + 38.75X]$

$X > 13.06$: $P_{ANET} = 61.25X - 800 - [38.75X + 800] + 625.00$
$= -[975 - 22.50X]$

NET FORCE CALCULATIONS:

RIGHT SIDE SOIL PASSIVE PRESSURE:

$P_{PR} = \gamma_E x + 2C = 61.25x + 800$

LEFT SIDE SOIL ACTIVE PRESSURE:

NEGATIVE ACTIVE PRESSURE SET TO ZERO
TO DEPTH = $2C/\gamma_E$ = $800/38.75 = 20.65'$

AT X BELOW LEFT SIDE SURFACE ($x > 20.65'$)
$P_{AL} = \gamma_E x - 2C = 38.75x - 800$

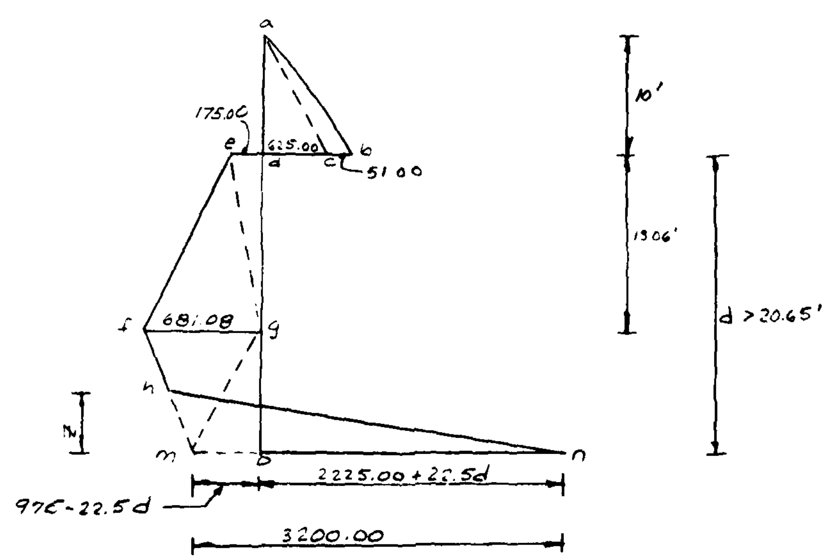
NET PASSIVE PRESSURE: $P_{PNET} = P_{PR} - P_{AL} + P_W$

$0 \le x \le 20.65$ $\quad P_{PNET} = 61.25x + 800 - 0 + 625.00$
$= 61.25x + 1425.00$

$x > 20.65$ $\quad P_{PNET} = 61.25x + 800 - [38.75x - 800] + 625.00$
$= 2225.00 + 22.5x$

DESIGN: ASSUME BOTTOM OF WALL BELOW X = 20.65'
AND TRANSITION FROM ACTIVE TO PASSIVE
STARTS BELOW X = 13.06'

NET PRESSURE DIAGRAM:



[illegible] REQUIRED PENETRATION d:

[illegible]	[illegible]	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P_1	[illegible]	$\frac{1}{2}\gamma_e \alpha H^2 = 340.01$	$4 + d$	$1360.04 + 340.01d$
P_2	acd	$625(10)/2 = 3125.00$	$10/3 + d = 3.33 + d$	$10406.25 + 3125.00d$
P_3	dcg	$-175.00(13.06)/2 = -1142.75$	$d - 13.06/3 = d - 4.35$	$4970.96 - 1142.75d$
P_4	efg	$-681.08(13.06)/2 = -4447.45$	$d - 2/3(13.06) = d - 8.71$	$38737.29 - 4447.45d$
P_5	efm	$-681.08(d-13.06)/2 = 4447.45 - 340.54d$	$2/3(d-13.06) = 0.67d - 8.71$	$5945.89d - 228.16d^2 - 38737.29$
P_6	emo	$-(915.00-22.50d)(d-13.06)/2 = 6366.75 - 634.43d + 11.25d^2$	$(d-13.06)/3 = 0.33d - 4.35$	$4860.80d - 258.30d^2 + 3.71d^3 - 27695.36$
P_7	kmn	$3200(z)/2 = 1600z$	$0.33z$	$528.00z^2$

$$\Sigma F_H = \Sigma P = 8687.01 - 974.97d + 11.25d^2 + 1600z$$

$$\Sigma M_o = -10958.10 + 8681.50d - 486.46d^2 + 3.71d^3 + 528.00z^2$$

FOR $\Sigma F_H = 0$ $\quad z = (974.97d - 11.25d^2 - 8687.01)/1600$

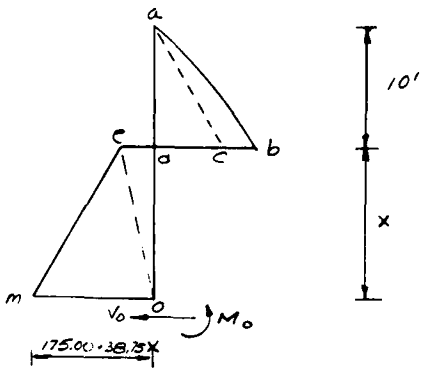
TRIAL d	z	ΣM_o
21	4.27	810
22	4.57	-4880

INTERPOLATE $d = 21 + 810/(810 + 4880) = 21.14$

21.14	4.31	28	OK

(PROGRAM 21.18)

MAXIMUM MOMENT OCCURS IN REGION $0 \le x \le 13.06$



FORCE	PRESS. DIAG.	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
F1	abc	340.01	4+x	1360.04 + 340.01 x
F2	acd	3125.00	3.33+x	10406.25 + 3125.00 x
F3	deo	$-175(x)/2 = -87.50x$	0.67x	$-58.63x^2$
F4	emo	$-(175.00+38.75x)x/2 = -87.50x - 19.38x^2$	0.33x	$-28.88x^2 - 6.40x^3$

$$\Sigma F_H = \Sigma F = -V_o = 3465.01 - 175.00x - 19.38x^2$$

$$\Sigma M_o = -M_o = 11766.29 + 3465.01x - 87.51x^2 - 6.40x^3$$

$$\text{FOR } V_o = 0 \qquad x = \frac{75.00 \pm \sqrt{(175.00)^2 - 4(-19.38)(3465.01)}}{2(-19.38)} = 9.60$$

$$M_o = M_{MAX} = -31303 \text{ LB-FT} \qquad (\text{PROGRAM } -31217 \text{ LB-FT})$$

PROBLEM "CANT3"

Cantilever Floodwall Design--Cohesive Soil
With Weak Layer Over Strong Layer

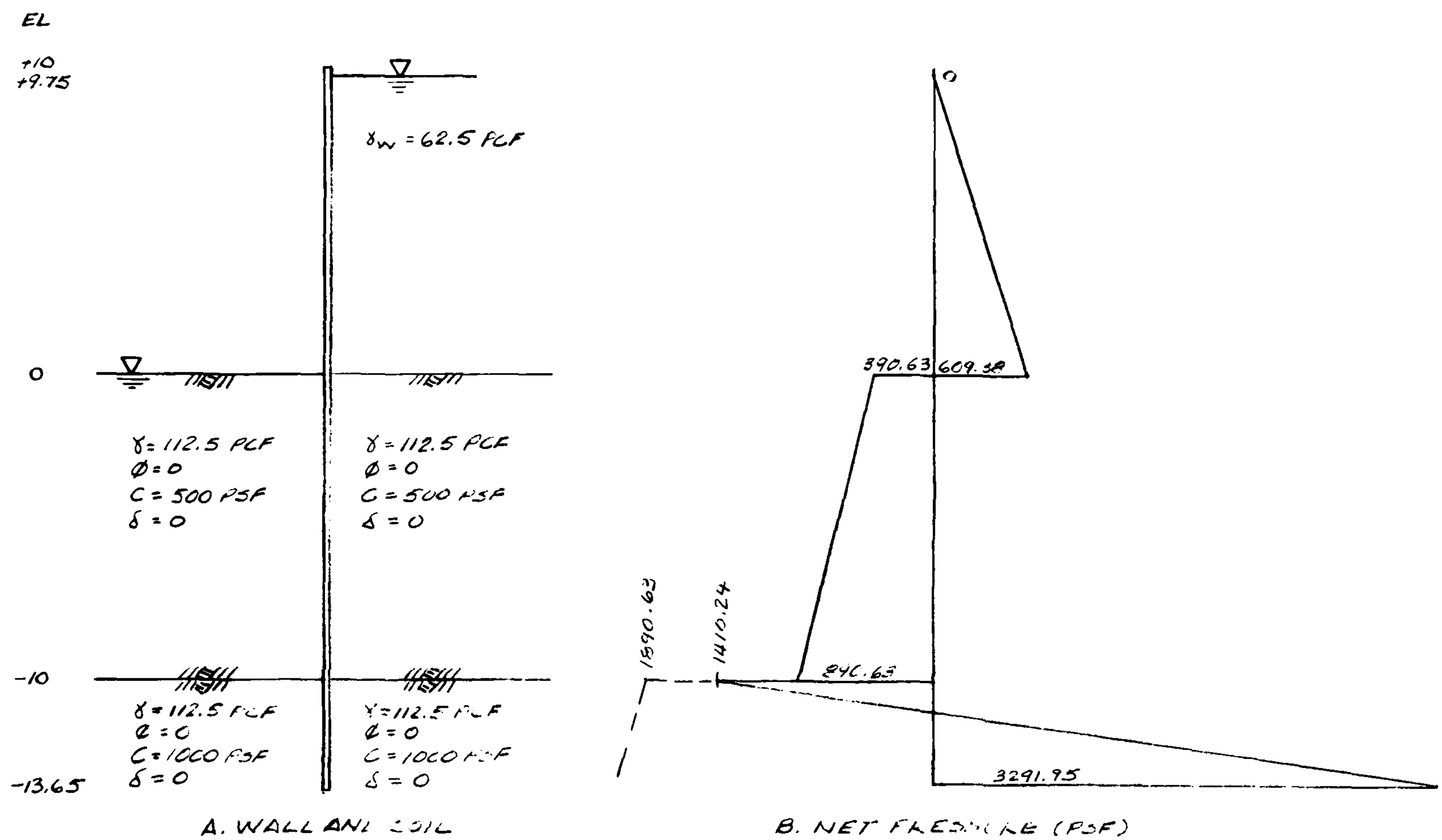


Figure B3. System and program results for problem "CANT3"

```
1000 3 PROBLEM - CANT3 - CANTILEVER WALL DESIGN
1010     FLOODWALL - COHESIVE LAYERED SOIL WITH
1020     HIGH STRENGTH LAYER UNDERLYING WEAKER LAYER
1030 C D
1040 10 1
1050 1 2
1060 0
1070 112.5 0 500 0 -10 0
1080 112.5 0 1000 0
1090 1 2
1100 0
1110 112.5 0 500 0 -10 0
1130 112.5 0 1000 0
1140 9.75 0 62.5 1
1150 0 N
1160 0 0 0
```

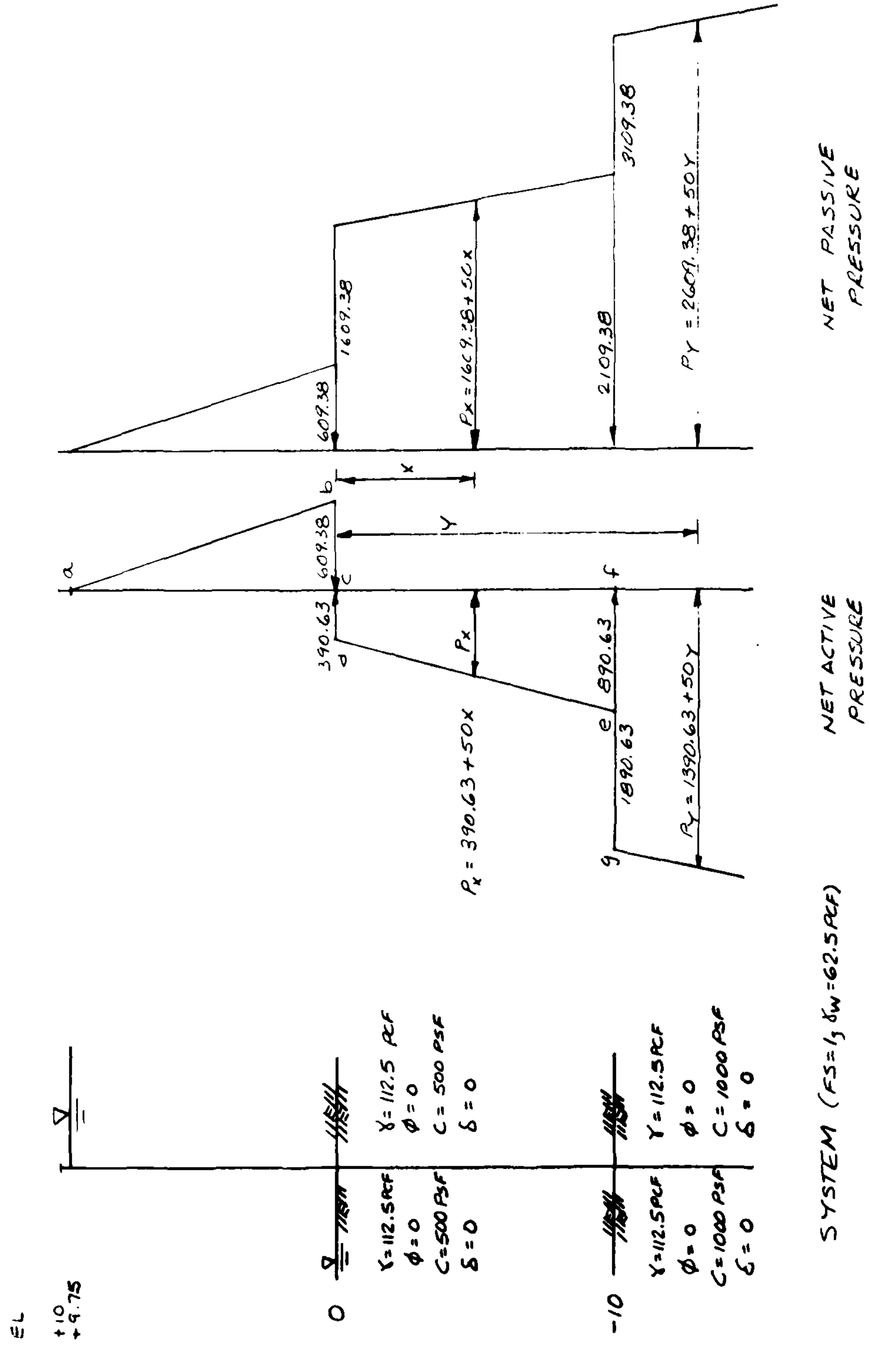
```
PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 08/17/79                         TIME: 13:33:54

2. RESULTS

2.A.--HEADING

PROBLEM - CANT3 - CANTILEVER WALL DESIGN
FLOODWALL - COHESIVE LAYERED SOIL WITH
HIGH STRENGTH LAYER UNDERLYING WEAKER LAYER


2.B.--SUMMARY OF RESULTS FOR CANTILEVER WALL DESIGN


     SOIL PRESSURES DETERMINED BY COULOMB
     COEFFICIENTS AND THEORY OF ELASTICITY
     EQUATIONS FOR SURCHARGE LOADS


     WALL BOTTOM:
          PENETRATION =      13.7 (FT)
          ELEVATION   =     -13.7 (FT)

     BENDING MOMENT:
          MAXIMUM     =   -18702. (LB-FT)
          ELEVATION   =      -5.6 (FT)

     SCALED DEFLECTION:
          MAXIMUM     =  5.11E+09 (LB-IN3)
          ELEVATION   =      10.0 (FT)

          (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
          OF ELASTICITY IN PSI TIMES PILE MOMENT OF
          INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)
```

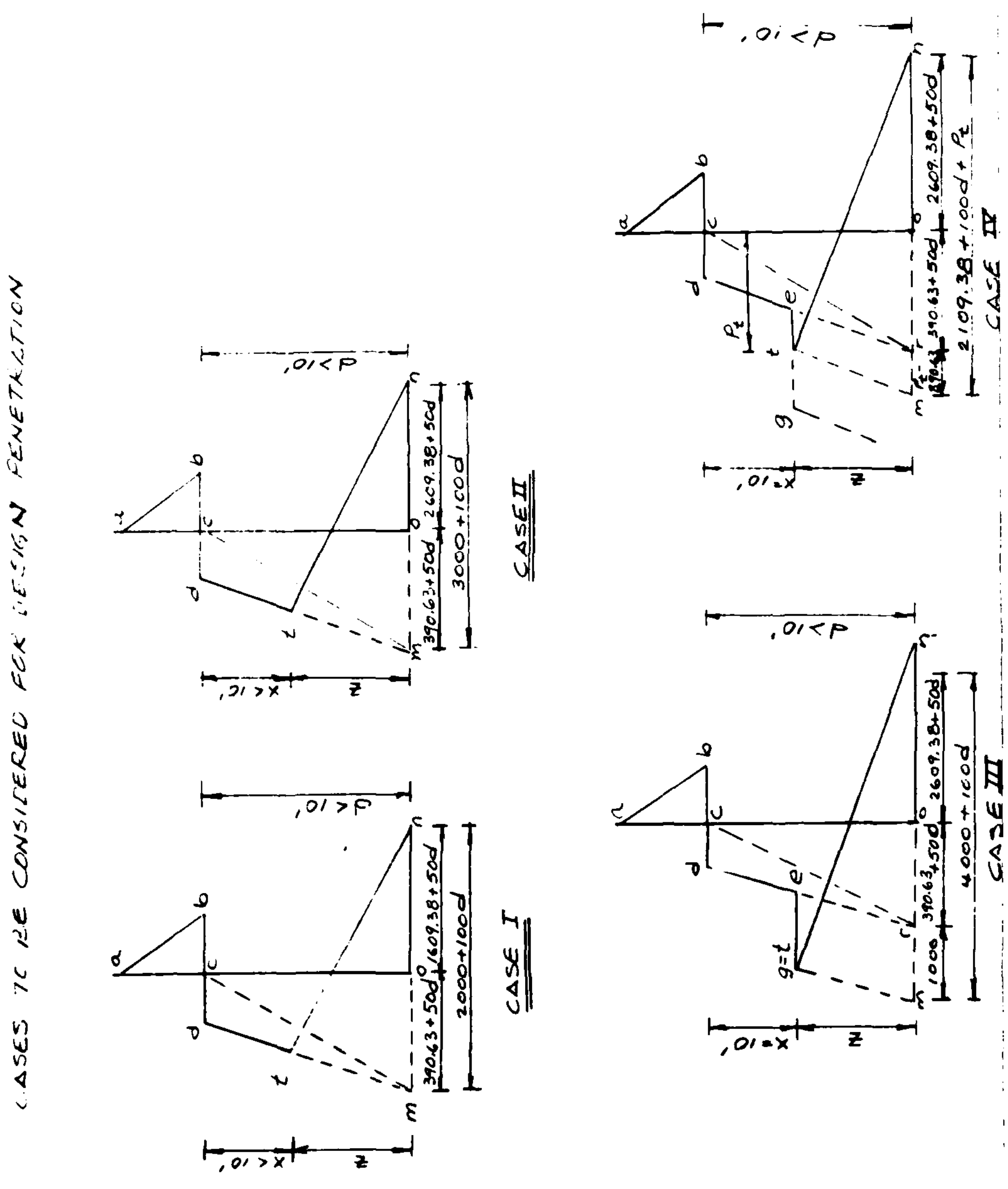
2.C.--COMPLETE RESULTS FOR CANTILEVER WALL DESIGN

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
10.00	-0.	0.	5.11E+09	0.00
9.75	0.	0.	5.03E+09	0.00
9.00	-4.	-18.	4.77E+09	46.88
8.00	-56.	-96.	4.42E+09	109.38
7.00	-217.	-236.	4.08E+09	171.88
6.00	-549.	-439.	3.73E+09	234.38
5.00	-1116.	-705.	3.39E+09	296.88
4.00	-1980.	-1033.	3.05E+09	359.38
3.00	-3204.	-1424.	2.71E+09	421.88
2.00	-4849.	-1877.	2.38E+09	484.38
1.00	-6978.	-2393.	2.05E+09	546.88
0.00	-9655.	-2971.	1.74E+09	609.38
0.00	-9655.	-2971.	1.74E+09	-390.63
-1.00	-12422.	-2555.	1.44E+09	-440.63
-2.00	-14748.	-2089.	1.17E+09	-490.63
-3.00	-16584.	-1574.	9.22E+08	-540.63
-4.00	-17879.	-1008.	7.02E+08	-590.63
-5.00	-18584.	-393.	5.13E+08	-640.63
-5.60	-18702.	0.	4.18E+08	-670.57
-6.00	-18648.	273.	3.55E+08	-690.63
-7.00	-18021.	989.	2.30E+08	-740.63
-8.00	-16654.	1754.	1.36E+08	-790.63
-9.00	-14496.	2570.	7.06E+07	-840.63
-10.00	-11497.	3436.	3.01E+07	-890.63
-10.00	-11497.	3436.	3.01E+07	-1410.24
-11.00	-7571.	4202.	9.29E+06	-122.50
-11.10	-7171.	4208.	8.10E+06	0.00
-13.00	-639.	1871.	4.05E+04	2452.97
-13.65	-0.	0.	0.	3291.95

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

Verification of Problem "CANT3" (Sheet 1 of 6)




CASES TO BE CONSIDERED FOR DESIGN PENETRATION
CASE I
CASE II
CASE III
CASE IV
390.63+50d
1609.38+50d
2000+100d
2609.38+50d
3000+100d
4000+100d
2109.38+100d+P_t

CASE I: $(d<10', x<10')$

FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	abc	$609.38(9.75)/2 = 2970.73$	$d+3.25$	$9654.87 + 2970.73d$
P2	cdm	$-390.63(d)/2 = -195.32d$	$0.67d$	$-130.86d^2$
P3	cmo	$-(390.63+50d)(d)/2 = -195.32d - 25d^2$	$0.33d$	$-64.46d^2 - 8.25d^3$
P4	dmn	$(2000+100d)(z)/2 = (1000+50d)z$	$0.33z$	$(330+16.50d)z^2$

$$\Sigma F_H = \Sigma P = 2970.73 - 390.64d - 25d^2 + (1000+50d)z$$

$$\Sigma M_o = 9654.87 + 2970.73d - 195.32d^2 - 8.25d^3 + (330+16.50d)z^2$$

FOR $\Sigma F_H = 0$ $\quad z = \dfrac{25d^2 + 390.64d - 2970.73}{1000+50d}$

TRIAL d	z	ΣM_o
8'	1.25	17418
9'	1.77	16055
10'	2.29	14176

$\therefore d > 10'$

CASE II ($d > 10'$, $x < 10'$)

FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P_1	abc	2970.73	$d + 3.25$	$9654.87 + 2970.73d$
P_2	cdm	$-195.32d$	$0.67d$	$-130.86d^2$
P_3	cmo	$-195.32d - 25d^2$	$0.33d$	$-64.46d^2 - 8.25d^3$
P_4	tmn	$(3000+100d)(z)/2 = (1500+50d)z$	$0.33z$	$(495+16.5d)z^2$

$$\Sigma F_H = 2970.73 - 390.64d - 25d^2 + (1500+50d)z$$

$$\Sigma M_0 = 9654.87 + 2970.73d - 195.32d^2 - 8.25d^3 + (495+16.5d)z^2$$

FOR $\Sigma F_H = 0$ $\quad z = \dfrac{25d^2 + 390.64d - 2970.73}{1500+50d}$

TRIAL d	z	ΣM_0
11'	2.12	10759
12'	2.53	7357
13'	2.95 (NG MAKES $x > 10'$)	

CONSIDER CASE II WITH ℄ AT POINT e (FIGURE SHEET 1 OF 6)
THEN $z = d - 10$

OR $\Sigma F_H = 2970.73 - 390.64d - 25d^2 + (1500 + 50d)(d-10)$

OR $\Sigma F_H = -12029.27 + 609.36d + 25d^2$

FOR $\Sigma F_H = 0$ $\quad d = \dfrac{-609.36 \pm \sqrt{(609.36)^2 - 4(25)(-12029.27)}}{2(25)}$

$d = 12.91$

$z = 2.91$

THEN $\Sigma M_0 = 3698$ NG

CASE III ($d > 10'$, t AT POINT g, FIGURE SHEET 1 OF 6)

FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	abc	2970.73	$d + 3.25$	$9654.87 + 2970.73d$
P2	cdr	$-195.32d$	$0.67d$	$-130.86d^2$
P_3	cro	$-195.32d - 25d^2$	$0.33d$	$-64.46d^2 - 8.25d^3$
P_4	etmr	$-1000(z) = -1000z$	$0.5z$	$-500z^2$
P_5	tmn	$(4000 + 100d)(z)/2 = (2000 + 50d)z$	$0.33z$	$(660 + 16.5d)z^2$

$$\Sigma F_H = 2970.73 - 390.64d - 25d^2 + (1000 + 50d)z$$

$$\Sigma M_o = 9654.87 + 2970.73d - 195.32d^2 - 8.25d^3 + (110 + 16.5d)z^2$$

BUT $z = d - 10$

$$\therefore \Sigma F_H = -7029.27 + 109.36d + 25d^2$$

FOR $\Sigma F_H = 0$ $\quad d = \dfrac{-109.36 \pm \sqrt{(109.36)^2 - 4(25)(-7029.27)}}{2(25)}$

$$d = 14.72$$
$$z = 4.72$$

$$\Sigma M_o = -7389$$

$\therefore$ POINT t MUST BE BETWEEN POINTS e AND g

Verification of Problem "CANT3" (Sheet 6 of 6)

CASE IV ($d > 10'$, POINT t BETWEEN POINTS e AND g)

FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	abc	2970.73	$d + 3.25$	$9654.87 + 2970.73d$
P2	cdr	$-195.32d$	$0.67d$	$-130.86d^2$
P3	cro	$-195.32d - 25d^2$	$0.33d$	$-64.46d^2 - 8.25d^3$
P4	etmr	$-(P_t - 890.63)(z)$	$0.5z$	$-(0.5P_t - 445.32)z^2$
P5	tmn	$(2109.38 + 100d + P_t)(z)/2$ $= (1054.69 + 50d + 0.5P_t)z$	$0.33z$	$(348.05 + 16.5d + 0.165P_t)z^2$

$$\Sigma F_H = 2970.73 - 390.64d - 25d^2 + (1954.32 + 50d - 0.5P_t)z$$

BUT $z = d - 10$

$$\therefore \Sigma F_H = -16572.47 + 1063.68d + 25d^2 + (5 - 0.5d)P_t$$

$$\Sigma M_o = 9654.87 + 2970.73d - 195.32d^2 - 8.25d^3$$
$$+ (793.37 + 16.5d - 0.335\,P_t)\,z^2$$

FOR $\Sigma F_H = 0$ $\quad P_t = \dfrac{16572.47 - 1063.68d - 25d^2}{5 - 0.5d}$

TRIAL d	P_t	ΣM_o
12	-208 NG	
13	986.91	3235
14	1609.53	-1913

INTERPOLATE $d = 13 + 3235/(3235 + 1913) = 13.63$

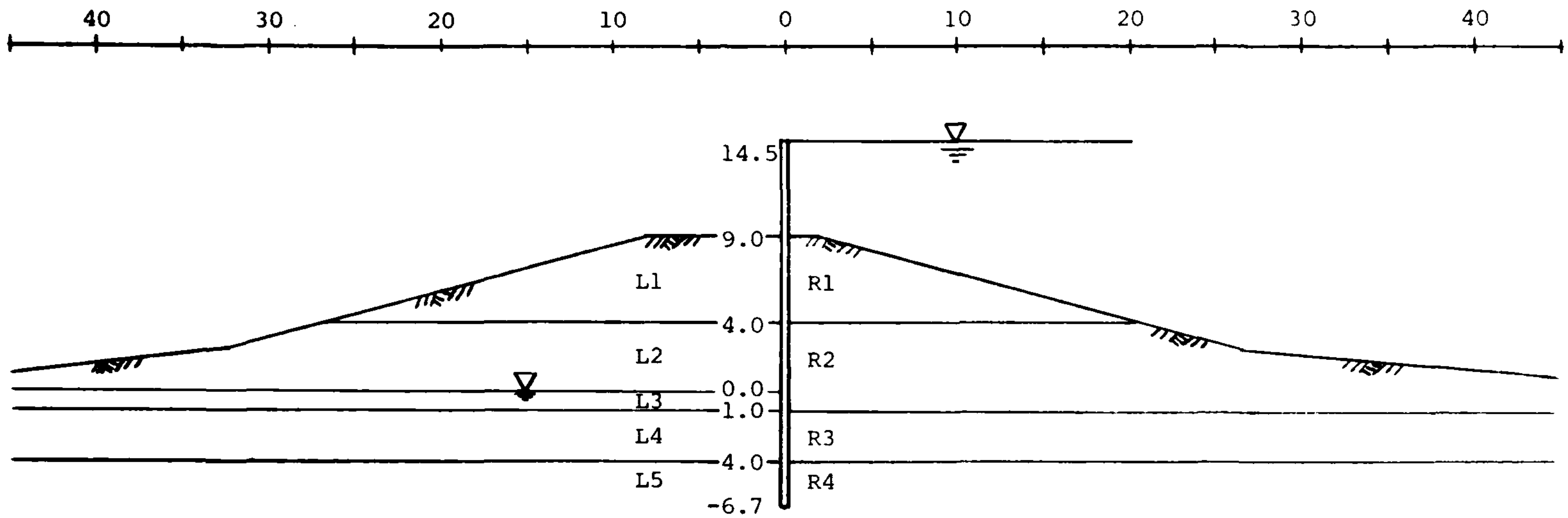
TRIAL d	P_t	ΣM_o
13.63	1415.93	137
13.64	1421.63	84
13.66	1432.94	-23 ← SAY OK
13.65	1427.30	+31

PROGRAM RESULTS

$d = 13.65'$
$P_t = 1410.25$ PSF

PROBLEM "CANT4"

Cantilever Floodwall Design--Granular Soil
With Irregular Surface

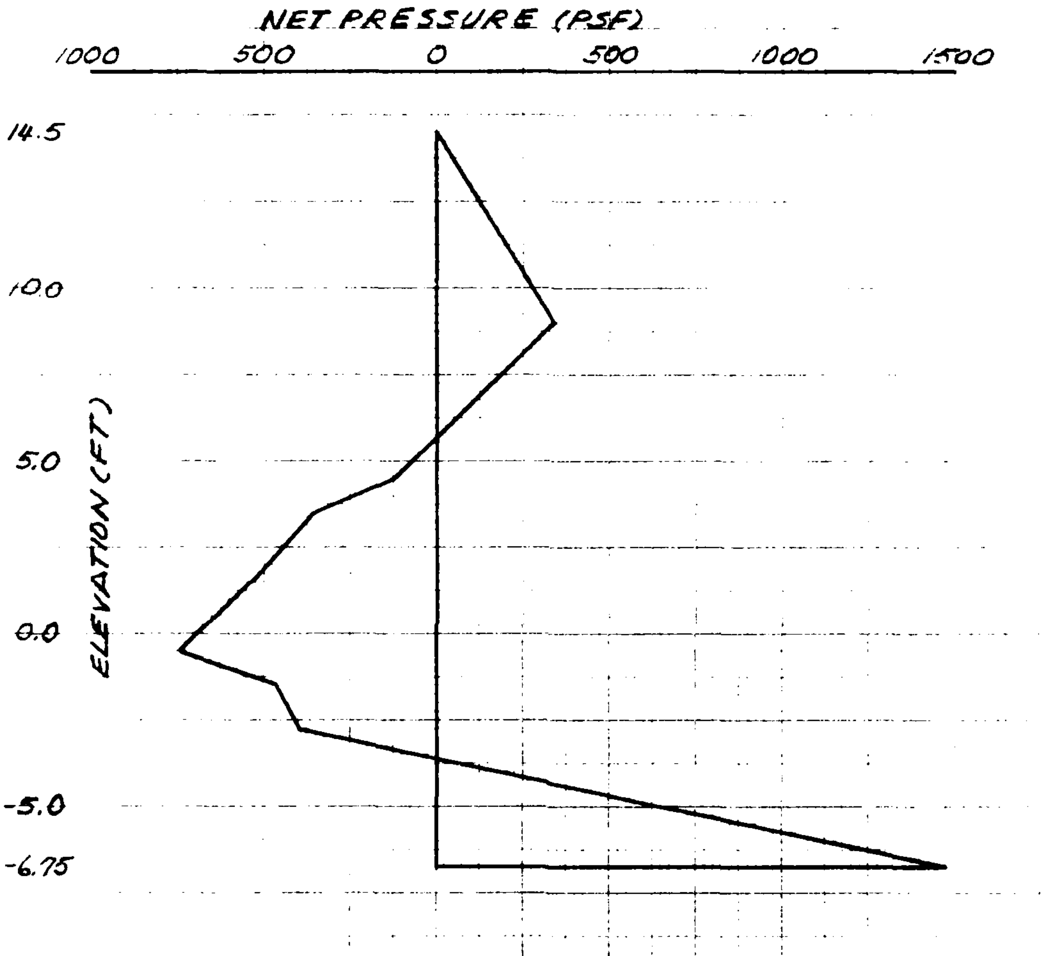


(a) Wall and Soil Profile

Layer	γ (PSF)	ϕ (DEG)
R1	102.5	23
R2	122.5	30
R3	102.5	23
R4	122.5	30
L1	107.5	23
L2	122.0	30
L3	122.5	30
L4	102.5	23
L5	122.5	30

(b) Soil Properties

Figure B4. System and program results for problem "CANT4"



C. NET PRESSURE

Figure B4. (Continued)

```
1000 3 PROBLEM - CANT4 - CANTILEVER WALL DESIGN
1010 FLOODWALL - LAYERED GRANULAR SOIL
1020 IRREGULAR SOIL SURFACE
1030 C D
1040 14.5 1.5
1050 4 4
1060 9 9 2.5 1
1070 2 26.5 45
1080 102.5 23 0 0 4 0
1090 122.5 30 0 0 -1 0
1100 102.5 23 0 0 -4 0
1110 122.5 30 0 0
1120 4 5
1130 9 9 2.5 1
1140 8 32.5 46
1150 107.5 23 0 0 4 0
1160 122 30 0 0 0 0
1170 122.5 30 0 0 -1 0
1180 102.5 23 0 0 -4 0
1190 122.5 30 0 0
1200 14.5 0 62.5 1
1210 0 N
1220 0 0 0
```

PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 12/12/80 TIME: 15:13:52

HEADING

PROBLEM - CANT4 - CANTILEVER WALL DESIGN
FLOODWALL - LAYERED GRANULAR SOIL
IRREGULAR SOIL SURFACE

ACTIVE AND PASSIVE SOIL PRESSURES

SOIL PRESSURES DETERMINED BY WEDGE METHOD.
WATER PRESSURES ARE NOT INCLUDED.

	LEFT SIDE		RIGHT SIDE	
ELEV (FT)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
14.50	0.00	0.00	0.00	0.00
13.50	0.00	0.00	0.00	0.00
12.50	0.00	0.00	0.00	0.00
11.50	0.00	0.00	0.00	0.00
10.50	0.00	0.00	0.00	0.00
9.50	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00
8.50	30.74	93.97	11.44	34.97
7.50	92.23	281.92	34.32	90.43
6.50	153.72	469.87	56.72	130.93
5.50	215.20	657.82	77.69	172.13
4.50	276.69	845.77	97.52	214.64
4.00	292.88	991.36	103.04	296.19
3.50	308.31	1145.81	110.20	382.10
2.50	366.70	1334.85	136.27	462.75
1.50	424.84	1510.86	161.88	566.25
.50	482.68	1711.63	187.16	672.91
0.00	507.49	1797.78	199.76	726.66
-.50	524.25	1850.97	212.38	780.67
-1.00	564.95	1751.44	235.37	777.03

-1.50	605.06	1626.08	257.08	757.08
-2.50	625.20	1592.05	277.19	800.84
-3.50	643.23	1549.89	297.18	845.24
-4.00	617.84	627.82	292.69	939.96
-4.50	592.51	366.05	289.64	989.54
-5.50	612.55	1700.59	315.14	1025.22
-6.50	633.06	1772.61	340.39	1179.46
-7.50	653.66	1845.96	365.56	1282.17
-8.50	673.76	1924.51	390.66	1386.76

```
PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 12/12/80                        TIME: 15:15:39

2. RESULTS

2.A.--HEADING

PROBLEM - CANT4 - CANTILEVER WALL DESIGN
FLOODWALL - LAYERED GRANULAR SOIL
IRREGULAR SOIL SURFACE


2.B.--SUMMARY OF RESULTS FOR CANTILEVER WALL DESIGN

     SOIL PRESSURES DETERMINED BY WEDGE METHOD


     WALL BOTTOM:
          PENETRATION =      15.7 (FT)
          ELEVATION   =      -6.7 (FT)

     BENDING MOMENT:
          MAXIMUM     =   -10949. (LB-FT)
          ELEVATION   =        .9 (FT)

     SCALED DEFLECTION:
          MAXIMUM     =  2.30E+09 (LB-IN3)
          ELEVATION   =      14.5 (FT)

          (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
          OF ELASTICITY IN PSI TIMES PILE MOMENT OF
          INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)
```

2.C.--COMPLETE RESULTS FOR CANTILEVER WALL DESIGN

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
14.50	-0.	0.	2.30E+09	0.00
13.50	-10.	-31.	2.12E+09	62.50
12.50	-83.	-125.	1.94E+09	125.00
11.50	-281.	-281.	1.76E+09	187.50
10.50	-667.	-500.	1.58E+09	250.00
9.50	-1302.	-781.	1.40E+09	312.50
9.00	-1733.	-945.	1.31E+09	343.75
8.50	-2247.	-1104.	1.22E+09	292.47
7.50	-3480.	-1346.	1.05E+09	189.90
6.50	-4903.	-1484.	8.88E+08	86.84
5.67	-6157.	-1520.	7.56E+08	0.00
4.50	-7905.	-1448.	5.85E+08	-123.24
4.00	-8609.	-1359.	5.17E+08	-232.07
3.50	-9255.	-1214.	4.53E+08	-348.10
2.50	-10278.	-816.	3.36E+08	-448.58
1.50	-10855.	-323.	2.38E+08	-536.48
.93	-10949.	0.	1.92E+08	-600.71
.50	-10891.	270.	1.58E+08	-649.47
0.00	-10674.	605.	1.25E+08	-691.77
-.50	-10283.	961.	9.65E+07	-732.34
-1.00	-9716.	1297.	7.26E+07	-609.82
-1.50	-8998.	1565.	5.29E+07	-462.75
-2.50	-7211.	2000.	2.49E+07	-408.61
-2.81	-6562.	2126.	1.88E+07	-389.07
-3.63	-4730.	2285.	7.88E+06	0.00
-4.81	-2164.	1956.	1.28E+06	559.41
-5.81	-567.	1159.	7.30E+04	1033.65
-6.74	-0.	-0.	0.	1472.31

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

APPENDIX C: EXAMPLE SOLUTIONS
FOR ANCHORED WALLS

PROBLEM "ANCH1"

**Anchored Wall Design--Granular Soil
With Uniform Surcharge**

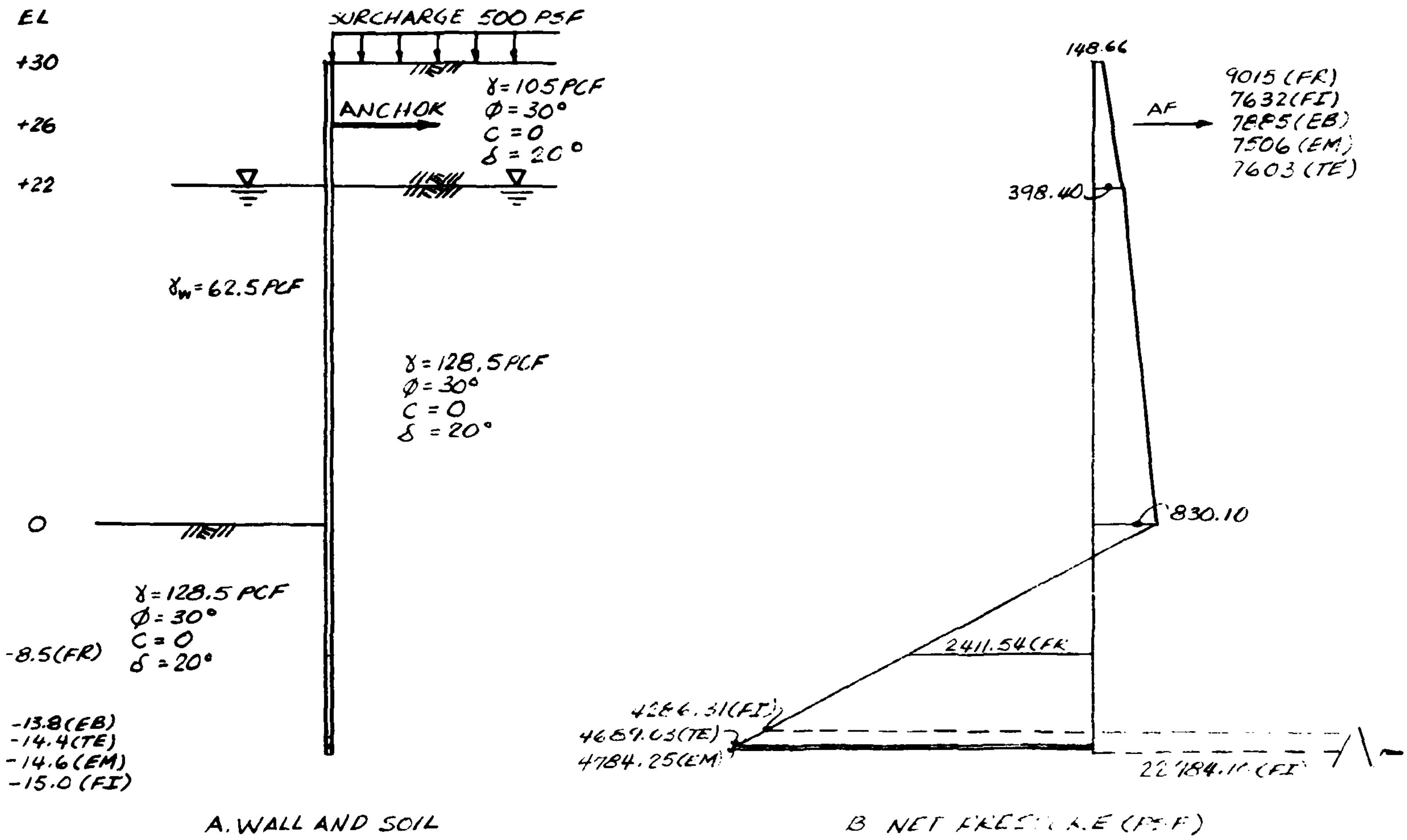
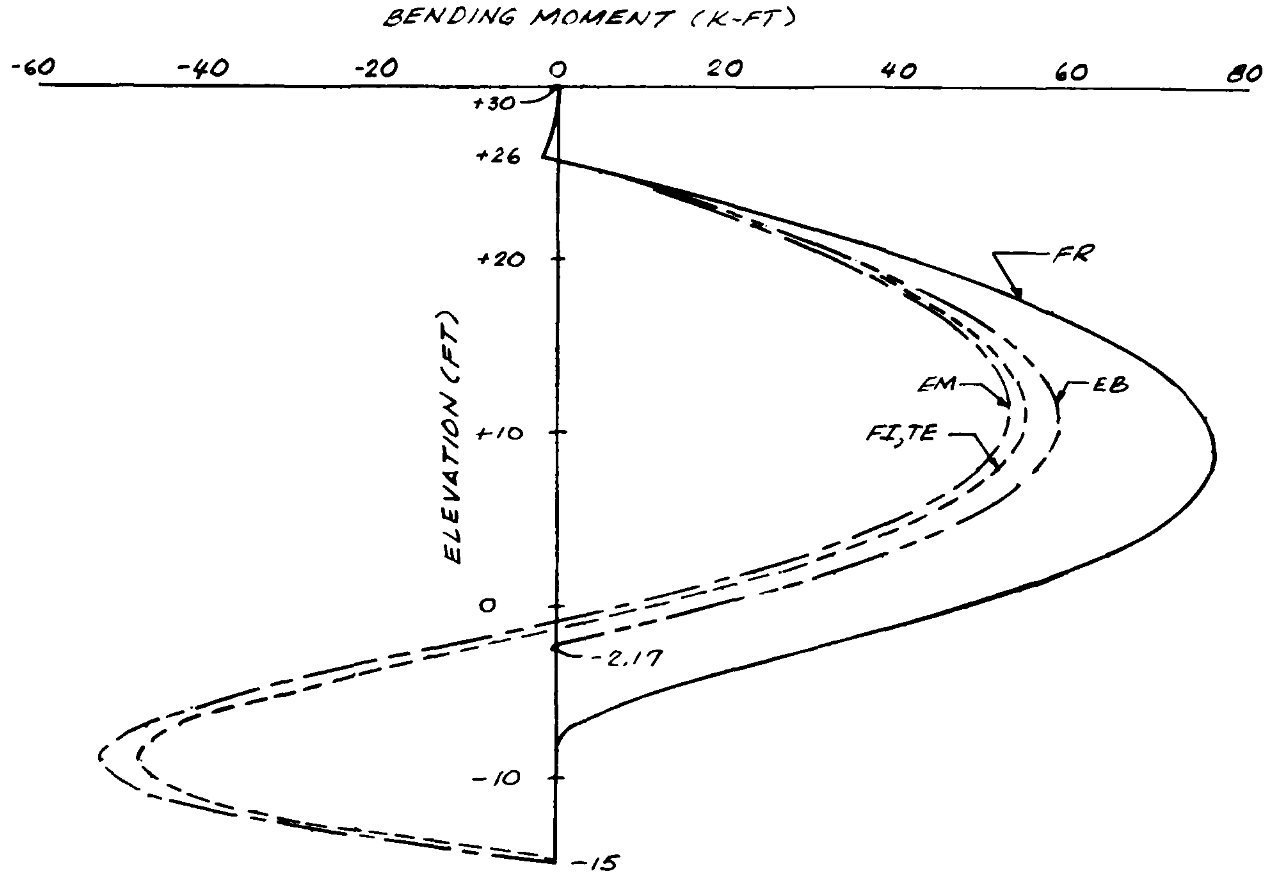
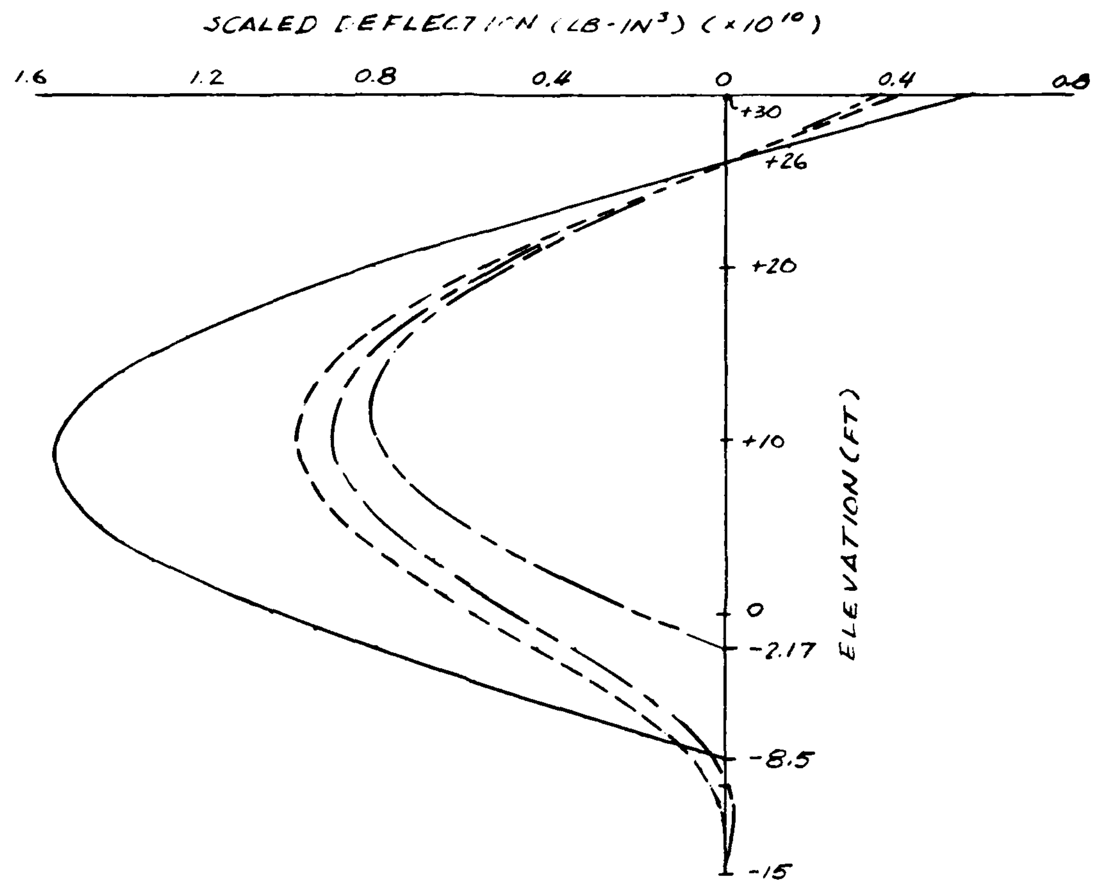


Figure C1. System and program results for problem "ANCH1"



C. BENDING MOMENT

Figure C1. (Continued)



D. SCALED DEFLECTION

Figure C1. (Continued)

```
1000 3 PROBLEM - ANCH1 - ANCHORED WALL DESIGN - GRANULAR SOIL
1010 FROM 'FOUNDATION ANALYSIS AND DESIGN' BY J. E. BOWLES
1020 EXAMPLE 13-3, PP 29-431
1030 A D 5 FR FI EB EM TE
1040 30 26 1
1050 1 2
1060 30
1070 105 30 0 20 22 0
1080 128.5 30 0 20
1090 1 1
1100 0
1110 128.5 30 0 20
1120 22 22 62.5 1
1130 0 U
1140 500
1150 0 0 0
```

PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 01/21/81   TIME: 10:47:16

1. INPUT DATA

1.A.--HEADING

PROBLEM - ANCH1 - ANCHORED WALL DESIGN - GRANULAR SOIL
FROM 'FOUNDATION ANALYSIS AND DESIGN' BY J. E. BOWLES
EXAMPLE 13-3, PP 29-431

1.B.--WALL TYPE, MODE, METHOD

```
     ANCHORED WALL DESIGN   BY FREE EARTH METHOD
     ANCHORED WALL DESIGN   BY FIXED EARTH METHOD
     ANCHORED WALL DESIGN   BY EQUIVALENT BEAM METHOD
     ANCHORED WALL DESIGN   BY EQUAL MOMENT METHOD
     ANCHORED WALL DESIGN   BY TERZAGHI METHOD
```

1.C.--WALL DESCRIPTION

```
     TOP OF WALL ELEVATION =   30.00 (FT)
     ANCHOR ELEVATION      =   26.00 (FT)
     FACTOR OF SAFETY      =    1.00
```

1.D.--RIGHT SIDE SOIL DESCRIPTION

```
     NUMBER OF RIGHT SIDE SURFACE POINTS =  1
     NUMBER OF RIGHT SIDE SOIL LAYERS    =  2
```

RIGHT SIDE SURFACE POINT COORDINATES

POINT NO.	ELEVATION (FT)	X-COORD (FT)
1	30.00	0.00

RIGHT SIDE SOIL LAYER DATA

LAYER NO.	UNIT WEIGHT (PCF)	INTERNAL FRICTION ANGLE (DEG)	COHESION (PSF)	WALL FRICTION ANGLE (DEG)	BOTTOM ELEV AT WALL (FT)	BOTTOM SLOPE (FT/FT)
1	105.00	30.00	0.00	20.00	22.00	1:0.0
2	128.50	30.00	0.00	20.00		

1.E.--LEFT SIDE SOIL DESCRIPTION

NUMBER OF LEFT SIDE SURFACE POINTS = 1
NUMBER OF LEFT SIDE SOIL LAYERS = 1

LEFT SIDE SURFACE POINT COORDINATES

POINT NO.	ELEVATION (FT)	X-COORD (FT)
1	0.00	0.00

LEFT SIDE SOIL LAYER DATA

LAYER NO.	UNIT WEIGHT (PCF)	INTERNAL FRICTION ANGLE (DEG)	COHESION (PSF)	WALL FRICTION ANGLE (DEG)	BOTTOM ELEV AT WALL (FT)	BOTTOM SLOPE (FT/FT)
1	128.50	30.00	0.00	20.00		

1.F.--WATER DATA

RIGHT SIDE ELEVATION = 22.00 (FT)
LEFT SIDE ELEVATION = 22.00 (FT)
WATER UNIT WEIGHT = 62.50 (PCF)
PRESSURE REDUCTION OPTION = 1

1.G.--SURCHARGE LOADS

NUMBER OF LINE LOADS = 0
DISTRIBUTED LOAD DISTRIBUTION = UNIF

UNIFORM SURCHARGE LOAD
LOAD = 500.00 PSF

1.H.--HORIZONTAL LOADS

NUMBER OF HORIZONTAL LINE LOADS = 0
NUMBER OF HORIZONTAL PRESSURE POINTS = 0
EARTHQUAKE ACCELERATION = 0.00 (G'S)

PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 01/21/81 TIME: 11:00:07

2. RESULTS

2.A.--HEADING

PROBLEM - ANCH1 - ANCHORED WALL DESIGN - GRANULAR SOIL
FROM 'FOUNDATION ANALYSIS AND DESIGN' BY J. E. BOWLES
EXAMPLE 13-3, PP 29-431

2.B.--SUMMARY OF RESULTS FOR ANCHORED WALL DESIGN

SOIL PRESSURES DETERMINED BY COULOMB
COEFFICIENTS AND THEORY OF ELASTICITY
EQUATIONS FOR SURCHARGE LOADS

METHOD	WALL PEN (FT)	BOTTOM ELEV (FT)	MAXIMUM BENDING MOMENT (LB-FT)	MAX SCALED DEFLECTION (LB-IN3)	ANCHOR FORCE (LB)
FREE EARTH :	8.5	-8.5	76537.	1.56E+10	9015.
FIXED EARTH:	15.0	-15.0	54551.	9.96E+09	7632.
EQUIV BEAM :	13.8	-13.8	58348.	8.24E+09	7885.
EQUAL MOM :	14.6	-14.6	52690.	9.15E+09	7506.
TERZAGHI :	14.4	-14.4	54512.	9.95E+09	7630.

(NOTE: PENETRATION FOR EQUIVALENT BEAM
METHOD DOES NOT INCLUDE INCREASE
PRESCRIBED BY DRAFT EM 1110-2-2906)

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

```
    DO YOU WANT COMPLETE RESULTS OUTPUT?
     ENTER 'YES' OR 'NO'
I>Y

    COMPLETE RESULTS ARE AVAILABLE FOR FOLLOWING
    METHODS OF ANALYSIS:
         FREE EARTH : ENTER 'FR' ON CUE
         FIXED EARTH: ENTER 'FI' ON CUE
         EQUIV BEAM : ENTER 'EB' ON CUE
         EQUAL MOM  : ENTER 'EM' ON CUE
         TERZAGHI   : ENTER 'TE' ON CUE

    ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED
I>FR
```

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY FREE EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-5.76E+09	148.66
29.00	-80.	-164.	-4.32E+09	179.87
28.00	-339.	-360.	-2.88E+09	211.09
27.00	-809.	-586.	-1.44E+09	242.31
26.00	-1522.	-844.	0.	273.53
26.00	-1522.	8171.	0.	273.53
25.00	6506.	7881.	1.44E+09	304.75
24.00	14230.	7561.	2.87E+09	335.96
23.00	21618.	7210.	4.28E+09	367.18
22.00	28639.	6827.	5.65E+09	398.40
21.00	35263.	6419.	6.97E+09	418.02
20.00	41470.	5991.	8.23E+09	437.65
19.00	47238.	5543.	9.42E+09	457.27
18.00	52550.	5076.	1.05E+10	476.89
17.00	57384.	4589.	1.15E+10	496.51
16.00	61722.	4083.	1.25E+10	516.14
15.00	65544.	3557.	1.33E+10	535.76
14.00	68830.	3012.	1.40E+10	555.38
13.00	71561.	2446.	1.45E+10	575.01
12.00	73716.	1862.	1.50E+10	594.63
11.00	75277.	1257.	1.53E+10	614.25
10.00	76224.	633.	1.55E+10	633.87
9.00	76537.	-11.	1.56E+10	653.50
8.00	76197.	-674.	1.55E+10	673.12
7.00	75183.	-1357.	1.53E+10	692.74
6.00	73476.	-2059.	1.50E+10	712.36
5.00	71058.	-2782.	1.45E+10	731.99
4.00	67907.	-3523.	1.40E+10	751.61
3.00	64004.	-4285.	1.33E+10	771.23
2.00	59331.	-5066.	1.24E+10	790.85
1.00	53866.	-5866.	1.15E+10	810.48
0.00	47591.	-6687.	1.05E+10	830.10

-1.00	40553.	-7325.	9.46E+09	446.77
-2.17	31814.	-7586.	8.11E+09	0.00
-3.00	25521.	-7452.	7.09E+09	-319.89
-4.00	18293.	-6940.	5.84E+09	-703.22
-5.00	11768.	-6046.	4.55E+09	-1086.55
-6.00	6329.	-4767.	3.24E+09	-1469.88
-7.00	2361.	-3106.	1.93E+09	-1853.22
-8.00	245.	-1061.	6.04E+08	-2236.55
-8.46	0.	-0.	0.	-2411.54

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'
I>Y

ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY FIXED EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-3.97E+09	148.66
29.00	-80.	-164.	-2.98E+09	179.87
28.00	-339.	-360.	-1.99E+09	211.09
27.00	-809.	-586.	-9.93E+08	242.31
26.00	-1522.	-844.	0.	273.53
26.00	-1522.	6788.	0.	273.53
25.00	5124.	6499.	9.94E+08	304.75
24.00	11465.	6179.	1.98E+09	335.96
23.00	17470.	5827.	2.94E+09	367.18
22.00	23109.	5444.	3.88E+09	398.40
21.00	28350.	5036.	4.77E+09	418.02
20.00	33174.	4608.	5.62E+09	437.65
19.00	37560.	4161.	6.41E+09	457.27
18.00	41489.	3694.	7.13E+09	476.89
17.00	44940.	3207.	7.79E+09	496.51
16.00	47896.	2701.	8.36E+09	516.14
15.00	50335.	2175.	8.85E+09	535.76
14.00	52238.	1629.	9.26E+09	555.38
13.00	53586.	1064.	9.57E+09	575.01
12.00	54359.	479.	9.80E+09	594.63
11.20	54551.	0.	9.90E+09	610.23
11.00	54538.	-125.	9.93E+09	614.25
10.00	54102.	-749.	9.96E+09	633.87
9.00	53032.	-1393.	9.90E+09	653.50
8.00	51309.	-2056.	9.75E+09	673.12
7.00	48913.	-2739.	9.51E+09	692.74
6.00	45824.	-3442.	9.19E+09	712.36
5.00	42022.	-4164.	8.79E+09	731.99
4.00	37489.	-4906.	8.31E+09	751.61
3.00	32204.	-5667.	7.77E+09	771.23
2.00	26148.	-6448.	7.18E+09	790.85
1.00	19301.	-7249.	6.54E+09	810.48
0.00	11643.	-8069.	5.86E+09	830.10
-1.00	3222	-8708.	5.17E+09	446.77

-2.17	-712[illegible]	-8968.	4.36E+09	0.00
-3.00	-1457[illegible].	-8835.	3.78E+09	-319.89
-4.00	-23186	-8323.	3.12E+09	-703.22
-5.00	-31094.	-7428.	2.49E+09	-1086.55
-6.00	-37915.	-6150.	1.92E+09	-1469.88
-7.00	-43266.	-4488.	1.42E+09	-1853.22
-8.00	-46764.	-2444.	9.88E+08	-2236.55
-9.00	-48026.	-15.	6.38E+08	-2619.88
-10.00	-4[illegible]7.	2796.	3.71E+08	-3003.21
-11.00	-42306.	5991.	1.83E+08	-3386.54
-12.00	-34557.	9569.	6.85E+07	-3769.87
-13.00	-23039.	13531.	1.30E+07	-4153.20
-13.35	-18088.	14996.	4.09E+06	-4286.31
-13.60	-14144.	15546.	0.	0.00
-14.97	0.	0.	-4.55E+06	22784.10

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

```
    DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'
I>Y
    ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED
I>EB
```

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY EQUIV BEAM METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	-0.	0.	-3.58E+09	148.66
29.00	-80.	-164.	-2.69E+09	179.87
28.00	-339.	-360.	-1.79E+09	211.09
27.00	-809.	-586.	-8.96E+08	242.31
26.00	-1522.	-844.	0.	273.53
26.00	-1522.	7041.	0.	273.53
25.00	5377.	6752.	8.97E+08	304.75
24.00	11971.	6432.	1.78E+09	335.96
23.00	18230.	6080.	2.65E+09	367.18
22.00	24121.	5697.	3.49E+09	398.40
21.00	29616.	5289.	4.28E+09	418.02
20.00	34692.	4861.	5.02E+09	437.65
19.00	39332.	4414.	5.71E+09	457.27
18.00	43513.	3947.	6.32E+09	476.89
17.00	47218.	3460.	6.86E+09	496.51
16.00	50427.	2954.	7.32E+09	516.14
15.00	53119.	2428.	7.69E+09	535.76
14.00	55276.	1882.	7.97E+09	555.38
13.00	56877.	1317.	8.15E+09	575.01
12.00	57903.	732.	8.24E+09	594.63
11.00	58334.	128.	8.23E+09	614.25
10.79	58348.	0.	8.20E+09	618.32
10.00	58152.	-496.	8.11E+09	633.87
9.00	57335.	-1140.	7.90E+09	653.50

8.00	55865.	-1803.	7.58E+09	673.12
7.00	53722.	-2486.	7.17E+09	692.74
6.00	50886.	-3189.	6.67E+09	712.36
5.00	47337.	-3911.	6.08E+09	731.99
4.00	43057.	-4653.	5.41E+09	751.61
3.00	38025.	-5414.	4.66E+09	771.23
2.00	32222.	-6195.	3.85E+09	790.85
1.00	25628.	-6996.	2.98E+09	810.48
0.00	18224.	-7816.	2.06E+09	830.10
-1.00	10056.	-8455.	1.12E+09	446.77
-2.17	0.	-8715.	0.	0.00

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

(NOTE: OUTPUT TABLE FOR EQUIVALENT BEAM
METHOD ENDS AT ASSUMED POINT OF INFLECTION)

DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'

I>Y
ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED
I>EM

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY EQUAL MOM METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	-0.	0.	-3.73E+09	148.66
29.00	-80.	-164.	-2.80E+09	179.87
28.00	-339.	-360.	-1.86E+09	211.09
27.00	-809.	-586.	-9.33E+08	242.31
26.00	-1522.	-844.	0.	273.53
26.00	-1522.	6661.	0.	273.53
25.00	4997.	6372.	9.34E+08	304.75
24.00	11212.	6052.	1.86E+09	335.96
23.00	17090.	5700.	2.76E+09	367.18
22.00	22602.	5317.	3.64E+09	398.40
21.00	27717.	4909.	4.48E+09	418.02
20.00	32414.	4481.	5.27E+09	437.65
19.00	36673.	4034.	6.00E+09	457.27
18.00	40475.	3567.	6.67E+09	476.89
17.00	43801.	3080.	7.27E+09	496.51
16.00	46629.	2574.	7.80E+09	516.14
15.00	48942.	2048.	8.24E+09	535.76
14.00	50718.	1502.	8.60E+09	555.38
13.00	51940.	937.	8.87E+09	575.01
12.00	52586.	352.	9.05E+09	594.63
11.41	52690.	0.	9.11E+09	606.14
11.00	52638.	-252.	9.15E+09	614.25
10.00	52076.	-876.	9.15E+09	633.87
9.00	50879.	-1520.	9.06E+09	653.50
8.00	49029.	-2183.	8.88E+09	673.12
7.00	46506.	-2866.	8.62E+09	692.74
6.00	43291.	-3569.	8.28E+09	712.36
5.00	39363.	-4291.	7.86E+09	731.99
4.00	34702.	-5033.	7.38E+09	751.61
3.00	29291.	-5794.	6.83E+09	771.23
2.00	23108.	-6575.	6.24E+09	790.85
1.00	16134.	-7376.	5.60E+09	810.48
0.00	8350.	-8196.	4.94E+09	830.10

-1.00	-197.	-8834.	4.26E+09	446.77
-2.17	-10696.	-9095.	3.48E+09	0.00
-3.00	-18249.	-8961.	2.93E+09	-319.89
-4.00	-26986.	-8450.	2.30E+09	-703.22
-5.00	-35020.	-7555.	1.72E+09	-1086.55
-6.00	-41968.	-6277.	1.20E+09	-1469.88
-7.00	-47446.	-4615.	7.45E+08	-1853.22
-8.00	-51071.	-2570.	3.77E+08	-2236.55
-9.00	-52459.	-142.	9.75E+07	-2619.88
-10.00	-51227.	2670.	-9.23E+07	-3003.21
-11.00	-46992.	5864.	-1.94E+08	-3386.54
-12.00	-39370.	9443.	-2.15E+08	-3769.87
-13.00	-27979.	13404.	-1.68E+08	-4153.20
-14.00	-12434.	17749.	-7.40E+07	-4536.53
-14.65	0.	20761.	0.	-4784.25

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

```
    DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'
I>Y
    ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED
I>TE
```

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY TERZAGHI METHOD

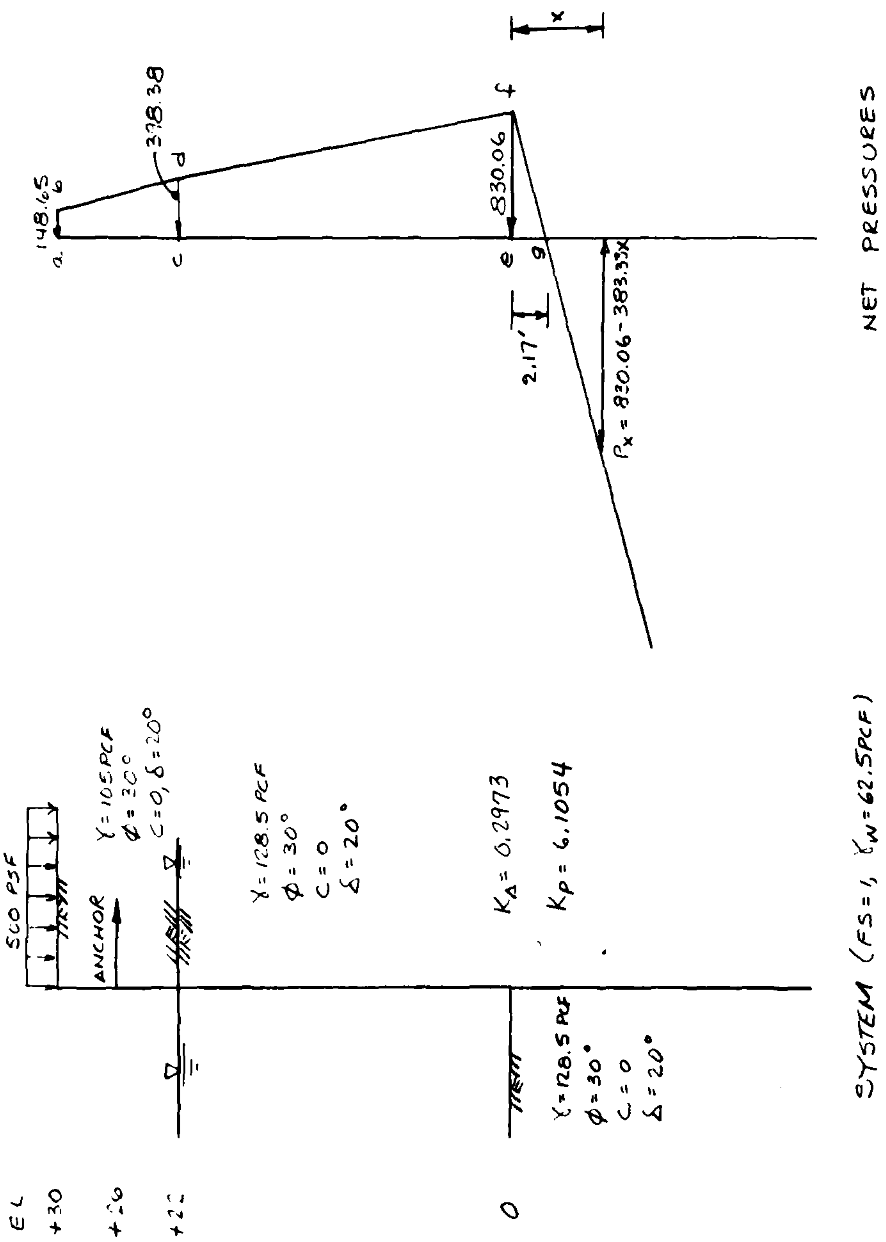
ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	-0.	0.	-3.96E+09	148.66
29.00	-80.	-164.	-2.97E+09	179.87
28.00	-339.	-360.	-1.98E+09	211.09
27.00	-809.	-586.	-9.92E+08	242.31
26.00	-1522.	-844.	0.	273.53
26.00	-1522.	6785.	0.	273.53
25.00	5121.	6496.	9.93E+08	304.75
24.00	11460.	6176.	1.98E+09	335.96
23.00	17463.	5824.	2.94E+09	367.18
22.00	23098.	5442.	3.87E+09	398.40
21.00	28337.	5033.	4.77E+09	418.02
20.00	33158.	4605.	5.61E+09	437.65
19.00	37541.	4158.	6.40E+09	457.27
18.00	41468.	3691.	7.13E+09	476.89
17.00	44917.	3204.	7.78E+09	496.51
16.00	47869.	2698.	8.35E+09	516.14
15.00	50306.	2172.	8.84E+09	535.76
14.00	52207.	1626.	9.25E+09	555.38
13.00	53552.	1061.	9.56E+09	575.01
12.00	54323.	476.	9.78E+09	594.63
11.21	54512.	0.	9.88E+09	610.15
11.00	54498.	-128.	9.91E+09	614.25
10.00	54060.	-752.	9.95E+09	633.87
9.00	52988.	-1396.	9.89E+09	653.50
8.00	51262.	-2059.	9.74E+09	673.12
7.00	48863.	-2742.	9.50E+09	692.74
6.00	45771.	-3445.	9.17E+09	712.36
5.00	41967.	-4167.	8.77E+09	731.99
4.00	37431.	-4909.	8.30E+09	751.61
3.00	32143.	-5670.	7.76E+09	771.23
2.00	26084.	-6451.	7.16E+09	790.85
1.00	19235.	-7252.	6.52E+09	810.48
0.00	11575.	-8072.	5.85E+09	830.10

-1.00	3151.	-8710.	5.16E+09	446.77
-2.17	-7203.	-8971.	4.34E+09	0.00
-3.00	-14652.	-8837.	3.77E+09	-319.89
-4.00	-23265.	-8326.	3.11E+09	-703.22
-5.00	-31176.	-7431.	2.48E+09	-1086.55
-6.00	-37999.	-6153.	1.91E+09	-1469.88
-7.00	-43353.	-4491.	1.41E+09	-1853.22
-8.00	-46854.	-2446.	9.80E+08	-2236.55
-9.00	-48118.	-18.	6.31E+08	-2619.88
-10.00	-46762.	2794.	3.66E+08	-3003.21
-11.00	-42403.	5988.	1.80E+08	-3386.54
-12.00	-34657.	9567.	6.75E+07	-3769.87
-13.00	-23142.	13528.	1.42E+07	-4153.20
-14.00	-7473.	17873.	3.49E+05	-4536.53
-14.40	0.	19708.	0.	-4689.03

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

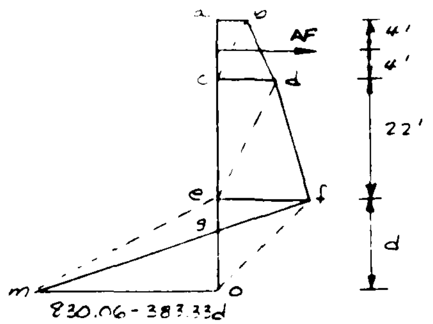
```
    DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'
I>N
    DO YOU WANT GEOMETRY AND/OR RESULTS PLOTTED?
    ENTER 'GEOMETRY', 'RESULTS', 'BOTH', OR 'NEITHER'
I>N
```

Verification of Problem "ANCH1" (Sheet 1 of 7)



Verification of Problem "ANCH1" (Sheet 2 of 7)

FREE EARTH METHOD



FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT AF	MOMENT ABOUT AF
P_1	abc	$(148.65)(8)/2 = 594.60$	$8/3 - 4 = -1.33$	-790.82
P_2	bcd	$(398.38)(8)/2 = 1573.52$	$16/3 - 4 = 1.33$	2092.78
P_3	cde	$(398.38)(22)/2 = 4382.18$	$22/3 + 4 = 11.33$	49650.10
P_4	def	$(830.06)(22)/2 = 9130.66$	$44/3 + 4 = 18.67$	170469.42
P_5	efo	$(830.06)d/2 = 415.03d$	$26 + 0.33d$	$10790.78d + 136.96d^2$
P_6	emo	$(830.06 - 383.33d)(d)/2 = 415.03d - 191.67d^2$	$26 + 0.67d$	$10790.78d - 4705.35d^2 - 128.42d^3$

$$\Sigma F_H = 15680.96 + 830.06\,d - 191.67d^2 - AF$$

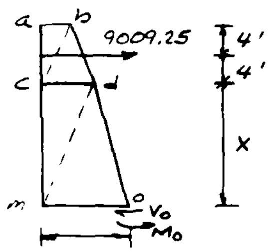
$$\Sigma M_{AF} = 221421.48 + 21581.56d - 4568.37d^2 - 128.42d^3$$

FOR $\Sigma M_{AF} = 0$:

TRIAL d	ΣM
8	35946
9	-48002
INTERPOLATE $d = 8 + 35946/(35946+48002)$	
8.43	1768
8.44	939
8.45	109 ← SAY OK (PROGRAM 8.46)
8.46	-723 (BOWLES 8.5)

FROM $\Sigma F_H = 0$; $AF = 9009.25$ (PROGRAM 9015 LB)
(BOWLES 9.1 KIP)

MAXIMUM MOMENT FOR FREE EARTH METHOD
MAXIMUM BETWEEN POINTS C AND C FIGURE SHEET 1 OF



$P_x = (500 + 8(105) + 66x)\, K_A = 398.38 + 19.62x$

FORCE	PRESS. DIAG.	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	abc	594.60	$x + 5.33$	$3169.22 + 594.60x$
P2	bcd	1573.52	$x + 2.67$	$4201.30 + 1573.52x$
P3	cdm	$398.38(x)/2 = 199.19x$	$0.67x$	$133.46x^2$
P4	dmo	$(398.38 + 19.62x)(x)/2 = 199.19x + 9.81x^2$	$0.33x$	$65.73x^2 + 3.24x^3$
AF		-9009.25	$x + 4$	$-36037 - 9009.25x$

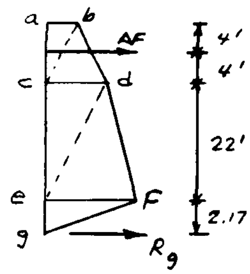
$$V_o = -\Sigma P = 6841.13 - 398.38x - 9.81x^2$$

$$M_o = -\Sigma M = 28666.48 + 6841.13x - 199.19x^2 - 3.24x^3$$

For $V_o = 0$ $\quad x = \dfrac{398.38 \pm \sqrt{(398.38)^2 - 4(-9.81)(6841.13)}}{2(-9.81)} = 13.01'$

$M_o = M_{MAX} = 76820^{\#\text{-FT}}$ (PROGRAM 76537)

DESIGN BY EQUIVALENT BEAM METHOD
ASSUME POINT OF INFLECTION AT POINT g FIGURE SHEET 1

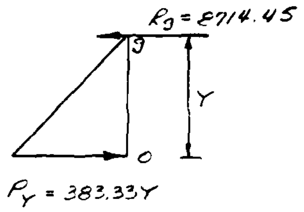


FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT AF	MOMENT ABOUT AF
P1	abc	594.60	-1.33	-790.82
P2	bcd	1573.52	1.33	2092.78
P3	cde	4382.18	11.33	49650.10
P4	def	9130.66	18.67	170469.42
P5	efg	(830.06)(2.17)/2 = 900.62	26.72	24064.57
AF		- AF	0	0
R_g		$- R_g$	28.17	$-28.17\,R_g$

$\Sigma F_H =$ $16581.58 - AF - R_g$

$\Sigma M_{AF} =$ $245486.05 - 28.17\,R_g$ $\therefore$ $R_g = 8714.45^{\#}$
$AF = 7867.13^{\#}$
(PROGRAM $7885^{\#}$)

PENETRATION BY EQUIVALENT BEAM METHOD



$$\Sigma M_o = 8714.45\,Y - (383.33Y)(Y/2)(Y/3) = 0$$

$$\therefore\ Y = 11.68'$$

$$d = 11.68 + 2.17 = 13.85' \quad (\text{PROGRAM } 13.8')$$

MAXIMUM MOMENT FOR EQUIV. BEAM METHOD
USE FACTORS FROM FREE EARTH METHOD WITH $\Delta F = 7867.13^{\#}$

$$V_o = 5699.01 - 398.38X - 9.81X^2$$

$$M_o = 24098.00 + 5699.01X - 199.19X^2 - 3.24X^3$$

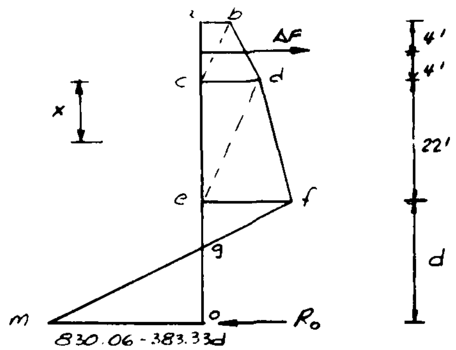
$$\text{FOR}\quad V_o = 0 \qquad X = \frac{398.38 \pm \sqrt{(398.38)^2 - 4(-9.81)(5699.01)}}{2(-9.81)}$$

$$X = 11.21'$$

$$M_o = M_{MAX} = 58387^{\#\text{-FT}} \quad (\text{PROGRAM } 58348^{\#\text{-FT}})$$

Verification of Problem "ANCH1" (Sheet 6 of 7)

DESIGN BY EQUAL MOMENT METHOD



FROM FREE EARTH METHOD AND ABOVE

$$\Sigma M_{AF} = 221421.48 + 21581.56d - 4568.39d^2 - 128.42d^3 + (26+d)R_o = 0 \quad ①$$

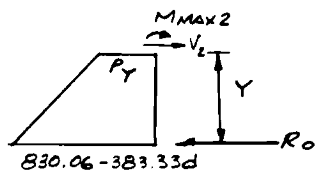
$$\Sigma F_H = 15680.96 + 830.06d - 191.67d^2 - \Delta F + R_o = 0 \quad ②$$

MAXIMUM MOMENT ABOVE e FROM FREE EARTH METHOD

MAX OCCURS AT $$x = \frac{398.38 - \sqrt{(398.38)^2 - 4(-9.81)(-2168.12 + \Delta F)}}{2(-9.81)} \quad ③$$

$$M_{MAX\,1} = 4\Delta F - 7370.52 + (\Delta F - 2168.12)x - 199.19x^2 - 3.24x^3 \quad ④$$

FOR MAXIMUM MOMENT BELOW e :



$$P_Y = 830.06 - 383.33(d - Y)$$

FOR $V_2 = 0$ $$[830.06 - 383.33(d-Y)]Y/2 + [830.06 - 383.33d]Y/2 + R_o = 0$$

OR $$Y = \frac{(383.33d - 830.06) \pm \sqrt{(383.33d - 830.06)^2 - 4(191.67)R_o}}{2(191.67)} \quad ⑤$$

THEN
$$M_{MAX\,2} = (415.03 - 191.67d + 127.78Y)Y^2 \quad ⑥$$

Verification of Problem "ANCH1" (Sheet 7 of 7)

PROCEDURE FOR DETERMINING d BY EQUAL MOM. METHOD

1. ASSUME d
2. CALCULATE K_0 FROM EQN 1
3. CALCULATE AF FROM EQN 2
4. CALCULATE X FROM EQN 3
5. CALCULATE M_{MAX1} FROM EQN 4
6. CALCULATE Y FROM EQN 5
7. CALCULATE M_{MAX2} FROM EQN 6
8. REPEAT UNTIL $|M_{MAX1}| = |M_{MAX2}|$

TRIAL d	K_0	AF	X	M_{MAX1}	Y	M_{MAX2}	
13'	14159.36	8238.87	11.81	64161	4.24	-27594	
14'	18105.64	7840.12	11.17	57978	5.08	-41786	*
15'	22345.37	7531.48	10.66	53369	5.90	-59390	
14.73'	21171.88	7492.43	10.60	52797	5.68	-54281	*
14.67	20913.99	7522.84	10.65	53242	5.63	-53167	OK

(PROGRAM $d = 14.65'$, $AF = 7502^{\#}$, $M_{MAX} = 52638^{\#'}$)

* INTERPOLATE

$d = 14'$ $\quad M_{MAX1} + M_{MAX2} = 16192$

$d = 15'$ $\quad M_{MAX1} + M_{MAX2} = -6021$

$$d = 14 + 16192/(16192 + 6021) = 14.73$$

$d = 14'$ $\quad M_{MAX1} + M_{MAX2} = 16192$

$d = 14.73'$ $\quad M_{MAX1} + M_{MAX2} = -1484$

$$d = 14 + 0.73\,[16192/(16192 + 1484)] = 14.67$$

PROBLEM "ANCH1A"

Analysis of Wall of Problem "ANCH1"
for Bottom of Wall at EL - 14.50

```
PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 01/21/81                          TIME: 12:09:06

2. RESULTS

2.A.--HEADING

PROBLEM - ANCH1A - SAME AS PROBLEM ANCH1 EXCEPT
ANALYZE FOR BOTTOM OF WALL AT EL -14.5, USE SHEET PILE
WITH MOMENT OF INERTIA = 220.4 IN**4


2.B.--SUMMARY OF RESULTS FOR ANCHORED   WALL ANALYSIS

      SOIL PRESSURES DETERMINED BY COULOMB
      COEFFICIENTS AND THEORY OF ELASTICITY
      EQUATIONS FOR SURCHARGE LOADS

                  FACTOR OF        MAXIMUM          MAXIMUM      ANCHOR
  METHOD           SAFETY      BENDING MOMENT     DEFLECTION      FORCE
                                  (LB-FT)            (IN)         (LB)
FREE EARTH :        1.46          135673.          5.81E+00     14019.
FIXED EARTH:         .98           52269.          1.47E+00      7388.
EQUIV BEAM :        1.03           60960.          1.36E+00      8177.
EQUAL MOM  :         .99           52068.          1.41E+00      7436.
TERZAGHI   :        1.01           55043.          1.58E+00      7686.


    DO YOU WANT COMPLETE RESULTS OUTPUT?
    ENTER 'YES' OR 'NO'
I>Y


    COMPLETE RESULTS ARE AVAILABLE FOR FOLLOWING
    METHODS OF ANALYSIS:
          FREE EARTH : ENTER 'FR' ON CUE
          FIXED EARTH: ENTER 'FI' ON CUE
          EQUIV BEAM : ENTER 'EB' ON CUE
          EQUAL MOM  : ENTER 'EM' ON CUE
          TERZAGHI   : ENTER 'TE' ON CUE
```

2.C.--COMPLETE RESULTS FOR ANCHORED WALL ANALYSIS
BY FREE EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (IN)	NET PRESSURE (PSF)
30.00	-0.	0.	-1.88E+00	202.15
29.00	-108.	-223.	-1.41E+00	244.61
28.00	-461.	-489.	-9.39E-01	287.06
27.00	-1101.	-797.	-4.70E-01	329.51
26.00	-2070.	-1148.	0.	371.96
26.00	-2070.	12870.	0.	371.96
25.00	10607.	12477.	4.70E-01	414.42
24.00	22870.	12042.	9.37E-01	456.87
23.00	34677.	11564.	1.40E+00	499.32
22.00	45983.	11043.	1.85E+00	541.77
21.00	56751.	10488.	2.29E+00	568.46
20.00	66950.	9906.	2.71E+00	595.14
19.00	76554.	9298.	3.12E+00	621.82
18.00	85537.	8662.	3.50E+00	648.51
17.00	93870.	8001.	3.86E+00	675.19
16.00	101529.	7312.	4.20E+00	701.88
15.00	108486.	6597.	4.51E+00	728.56
14.00	114714.	5855.	4.79E+00	755.25
13.00	120187.	5086.	5.04E+00	781.93
12.00	124878.	4291.	5.25E+00	808.61
11.00	128760.	3469.	5.44E+00	835.30
10.00	131807.	2620.	5.58E+00	861.98
9.00	133992.	1745.	5.70E+00	888.67
8.00	135288.	843.	5.77E+00	915.35
7.00	135669.	-86.	5.81E+00	942.04
6.00	135108.	-1041.	5.81E+00	968.72
5.00	133579.	-2023.	5.78E+00	995.40
4.00	131054.	-3032.	5.71E+00	1022.09
3.00	127506.	-4067.	5.60E+00	1048.77
2.00	122910.	-5129.	5.46E+00	1075.46
1.00	117239.	-6218.	5.29E+00	1102.14
0.00	110465.	-7334.	5.09E+00	1128.83
-1.00	102605.	-8350.	4.85E+00	903.40

-2.00	93841.	-9140.	4.59E+00	677.98
-3.00	84399.	-9706.	4.30E+00	452.55
-4.00	74505.	-10045.	3.99E+00	227.13
-5.00	64384.	-10160.	3.66E+00	1.70
-6.00	54260.	-10049.	3.31E+00	-223.72
-7.00	44361.	-9712.	2.95E+00	-449.15
-8.00	34911.	-9151.	2.58E+00	-674.57
-9.00	26135.	-8363.	2.19E+00	-900.00
-10.00	18259.	-7351.	1.80E+00	-1125.42
-11.00	11509.	-6112.	1.40E+00	-1350.84
-12.00	6109.	-4649.	1.00E+00	-1576.27
-13.00	2286.	-2960.	6.03E-01	-1801.69
-14.00	265.	-1046.	2.02E-01	-2027.12
-14.50	0.	-4.	7.09E-04	-2139.83
-14.50	0.	-0.	0.	-2140.23

2.C.--COMPLETE RESULTS FOR ANCHORED WALL ANALYSIS
BY FIXED EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	DEFLECTION (IN)	NET PRESSURE (PSF)
30.00	0.	0.	-5.89E-01	145.26
29.00	-78.	-161.	-4.42E-01	175.76
28.00	-331.	-352.	-2.95E-01	206.27
27.00	-791.	-573.	-1.48E-01	236.77
26.00	-1487.	-825.	0.	267.27
26.00	-1487.	6563.	0.	267.27
25.00	4936.	6280.	1.48E-01	297.78
24.00	11062.	5967.	2.94E-01	328.28
23.00	16860.	5624.	4.37E-01	358.79
22.00	22299.	5250.	5.76E-01	389.29
21.00	27351.	4851.	7.09E-01	408.47
20.00	31994.	4433.	8.34E-01	427.64
19.00	36210.	3995.	9.51E-01	446.81
18.00	39978.	3539.	1.06E+00	465.99
17.00	43281.	3063.	1.15E+00	485.16
16.00	46098.	2569.	1.24E+00	504.34
15.00	48412.	2055.	1.31E+00	523.51
14.00	50201.	1522.	1.37E+00	542.68
13.00	51448.	969.	1.41E+00	561.86
12.00	52133.	398.	1.45E+00	581.03
11.32	52269.	0.	1.46E+00	594.02
11.00	52238.	-193.	1.46E+00	600.21
10.00	51741.	-803.	1.47E+00	619.38
9.00	50626.	-1431.	1.46E+00	638.55
8.00	48872.	-2080.	1.43E+00	657.73
7.00	46460.	-2747.	1.39E+00	676.90
6.00	43371.	-3433.	1.34E+00	696.08
5.00	39587.	-4139.	1.28E+00	715.25
4.00	35087.	-4864.	1.21E+00	734.43
3.00	29852.	-5608.	1.13E+00	753.60
2.00	23864.	-6371.	1.04E+00	772.77
1.00	17104.	-7154.	9.40E-01	791.95
0.00	9551.	-7955.	8.39E-01	811.12

-1.00	1257.	-8567.	7.36E-01	412.41
-2.00	-7450.	-8780.	6.32E-01	13.69
-3.00	-16170.	-8594.	5.30E-01	-385.02
-4.00	-24506.	-8010.	4.32E-01	-783.74
-5.00	-32057.	-7027.	3.41E-01	-1182.45
-6.00	-38426.	-5645.	2.59E-01	-1581.16
-7.00	-43214.	-3864.	1.87E-01	-1979.88
-8.00	-46022.	-1685.	1.26E-01	-2378.59
-9.00	-46452.	893.	7.83E-02	-2777.31
-10.00	-44104.	3869.	4.28E-02	-3176.02
-11.00	-38580.	7245.	1.91E-02	-3574.73
-12.00	-29482.	11019.	5.82E 03	-3973.45
-12.94	-17317.	14929.	5.63E 04	-4348.14
-13.18	-13584.	15460.	0.	0.00
-14.50	-0.	0.	-6.38E-04	23460.09

PROBLEM "ANCH2"

Anchored Wall Design--Granular Backfill, Cohesive Soil
Horizontal Line Load at Top of Wall

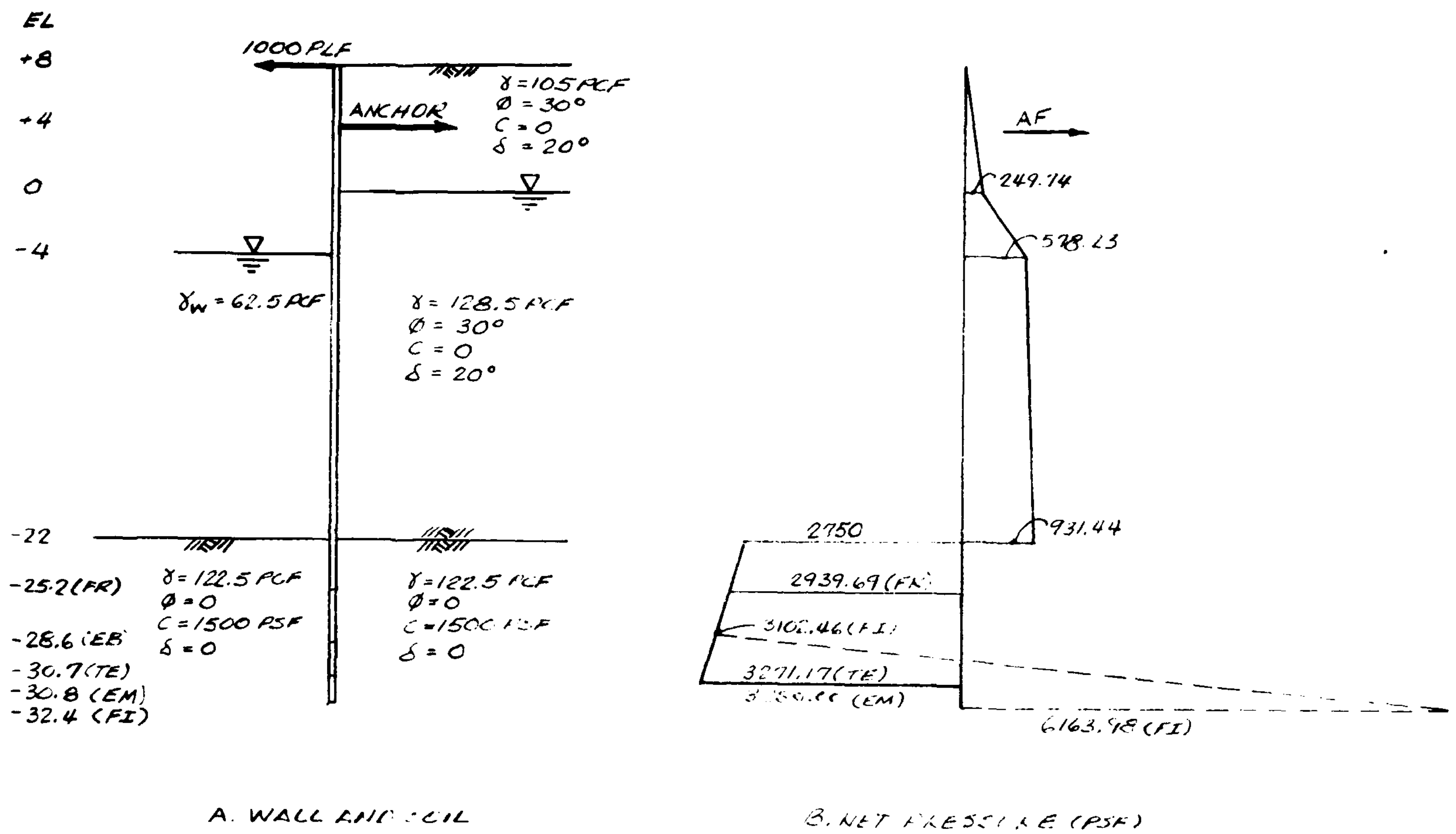


Figure C2. System and program results for problem "ANCH2"

```
    PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
    OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
    DATE: 01/21/81                         TIME: 12:20:27


    ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
    ENTER 'TERMINAL' OR 'FILE'
I>T


    ENTER NUMBER OF HEADER LINES (1 TO 4)
I>3

    ENTER FIRST  HEADER LINE (1 TO 70 CHARACTERS)
I>PROBLEM - ANCH2 - ANCHORED WALL DESIGN

    ENTER SECOND HEADER LINE (1 TO 70 CHARACTERS)
I>LAYERED SOIL - GRANULAR BACKFILL - COHESIVE SUBOSOIL

    ENTER THIRD  HEADER LINE (1 TO 70 CHARACTERS)
I>HORIZONTAL LINE LOAD AT TOP OF WALL

    ENTER WALL TYPE: 'CANT' OR 'ANCH'
I>A

    ENTER MODE: 'DESIGN' OR 'ANALYSIS'
I>D

    ENTER NUMBER OF METHODS TO BE USED IN
    ANCHORED WALL DESIGN OR ANALYSIS (1 TO 5)
I>5


    WALL DATA, ENTER VALUES UNDER HEADINGS

          ELEVATION AT            FACTOR
        TOP OF                      OF
         WALL      ANCHOR         SAFETY
         (FT)       (FT)
I>8 4 1
```

```
    RIGHT SIDE SOIL DESCRIPTION. ENTER

      NUMBER OF          NUMBER OF
    SURFACE POINTS      SOIL LAYERS
      (1 TO 15)          (1 TO 15)
I>1 3

    ENTER  1 SURFACE POINT ELEVATIONS UNDER HEADINGS
    SUREL( 1)  SUREL(
      (FT)       (FT)       (FT)       (FT)       (FT)
I>8

    ENTER SOIL LAYER DATA UNDER HEADINGS. ONE LINE PER LAYER

    SATURATED  INTERNAL                 WALL     BOTTOM
       UNIT    FRICTION               FRICTION    ELEV       BOTTOM
      WEIGHT    ANGLE     COHESION     ANGLE     AT WALL     SLOPE
      (PCF)     (DEG)      (PSF)       (DEG)      (FT)       (FT/FT)
I>105 30 0 20 0 0
I>128.5 30 0 20 -22 0
I>122.5 0 1500 0

    LEFT SIDE SOIL DESCRIPTION. ENTER

      NUMBER OF          NUMBER OF
    SURFACE POINTS      SOIL LAYERS
      (1 TO 15)          (1 TO 15)
I>1 1

    ENTER  1 SURFACE POINT ELEVATIONS UNDER HEADINGS
    SUREL( 1)  SUREL(
      (FT)       (FT)       (FT)       (FT)       (FT)
I>-22

    ENTER SOIL LAYER DATA UNDER HEADINGS. ONE LINE PER LAYER

    SATURATED  INTERNAL                 WALL     BOTTOM
       UNIT    FRICTION               FRICTION    ELEV       BOTTOM
      WEIGHT    ANGLE     COHESION     ANGLE     AT WALL     SLOPE
      (PCF)     (DEG)      (PSF)       (DEG)      (FT)       (FT/FT)
I>122.5 0 1500 0
```

```
    WATER DATA, ENTER VALUES UNDER HEADINGS

    RIGHT SIDE      LEFT SIDE       UNIT        PRESSURE
    ELEVATION       ELEVATION       WEIGHT       OPTION
      (FT)            (FT)          (PCF)       (0 OR 1)
I>0 -4 62.5 1


    SURCHARGE LOADS ON RIGHT SIDE SURFACE

    ENTER NUMBER OF LINE LOADS (0 TO 4)
I>0

    DISTRIBUTED LOAD DESCRIPTION
    ENTER 'NONE', 'STRIP', 'RAMP', 'TRIANG', OR 'UNIF'
I>NONE


    HORIZONTAL LOAD DATA. ENTER
    NUMBER OF       NUMBER OF       EARTHQUAKE
    LINE LOADS    PRESSURE PTS    ACCELERATION
     (0 TO 4)    (0 OR 2 TO 12)       (G'S)
I>1 0 0


    ENTER HORIZONTAL LINE LOAD DATA UNDER HEADINGS
      LOAD(1)                 LOAD(
   ELEV      LOAD        ELEV      LOAD        ELEV      LOAD        ELEV      LOAD
  (FT)      (PLF)       (FT)      (PLF)       (FT)      (PLF)       (FT)      (PLF)
I>8 1000
    INPUT COMPLETE. NO ERRORS DETECTED
    DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'
I>N




    DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR
    TERMINAL, TO A FILE, TO BOTH, OR NEITHER?
    ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'
I>T
```

```
PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 01/21/81                          TIME: 12:26:09

1. INPUT DATA

1.A.--HEADING

PROBLEM - ANCH2 - ANCHORED WALL DESIGN
LAYERED SOIL - GRANULAR BACKFILL - COHESIVE SUBSOIL
HORIZONTAL LINE LOAD AT TOP OF WALL


1.B.--WALL TYPE, MODE, METHOD
     ANCHORED WALL DESIGN   BY FREE EARTH METHOD
     ANCHORED WALL DESIGN   BY FIXED EARTH METHOD
     ANCHORED WALL DESIGN   BY EQUIVALENT BEAM METHOD
     ANCHORED WALL DESIGN   BY EQUAL MOMENT METHOD
     ANCHORED WALL DESIGN   BY TERZAGHI METHOD


1.C.--WALL DESCRIPTION
     TOP OF WALL ELEVATION =    8.00 (FT)
     ANCHOR ELEVATION      =    4.00 (FT)
     FACTOR OF SAFETY      =    1.00


1.D.--RIGHT SIDE SOIL DESCRIPTION
     NUMBER OF RIGHT SIDE SURFACE POINTS =  1
     NUMBER OF RIGHT SIDE SOIL LAYERS    =  3


     RIGHT SIDE SURFACE POINT COORDINATES
      POINT      ELEVATION      X-COORD
      NO.          (FT)          (FT)
       1           8.00          0.00
```

RIGHT SIDE SOIL LAYER DATA

LAYER NO.	UNIT WEIGHT (PCF)	INTERNAL FRICTION ANGLE (DEG)	COHESION (PSF)	WALL FRICTION ANGLE (DEG)	BOTTOM ELEV AT WALL (FT)	BOTTOM SLOPE (FT/FT)
1	105.00	30.00	0.00	20.00	0.00	1:0.0
2	128.50	30.00	0.00	20.00	-22.00	1:0.0
3	122.50	0.00	1500.00	0.00		

1.E.--LEFT SIDE SOIL DESCRIPTION

NUMBER OF LEFT SIDE SURFACE POINTS = 1
NUMBER OF LEFT SIDE SOIL LAYERS = 1

LEFT SIDE SURFACE POINT COORDINATES

POINT NO.	ELEVATION (FT)	X-COORD (FT)
1	-22.00	0.00

LEFT SIDE SOIL LAYER DATA

LAYER NO.	UNIT WEIGHT (PCF)	INTERNAL FRICTION ANGLE (DEG)	COHESION (PSF)	WALL FRICTION ANGLE (DEG)	BOTTOM ELEV AT WALL (FT)	BOTTOM SLOPE (FT/FT)
1	122.50	0.00	1500.00	0.00		

1.F.--WATER DATA

RIGHT SIDE ELEVATION = 0.00 (FT)
LEFT SIDE ELEVATION = -4.00 (FT)
WATER UNIT WEIGHT = 62.50 (PCF)
PRESSURE REDUCTION OPTION = 1

1.G.--SURCHARGE LOADS

NUMBER OF LINE LOADS = 0
DISTRIBUTED LOAD DISTRIBUTION = NONE

```
     1.H.--HORIZONTAL LOADS
          NUMBER OF HORIZONTAL LINE LOADS          =     1
          NUMBER OF HORIZONTAL PRESSURE POINTS     =     0
          EARTHQUAKE ACCELERATION                  =     0.00 (G'S)

          HORIZONTAL LINE LOADS ON WALL
           LOAD        ELEVATION        LOAD
            NO.           (FT)          (PLF)
             1            8.00         1000.00

     DO YOU WANT A PLOT OF INPUT GEOMETRY?
     ENTER 'YES' OR 'NO'
I>N
     INPUT SEQUENCE COMPLETE.
     DO YOU WANT TO CONTINUE SOLUTION?
     ENTER 'YES' OR 'NO'
I>Y
     DO YOU WANT ACTIVE AND PASSIVE SOIL PRESSURES
     PRINTED AT YOUR TERMINAL?  ENTER 'YES' OR 'NO'
I>N
     SOLUTION COMPLETE
     DO YOU WANT RESULTS PRINTED AT YOUR TERMINAL,
     WRITTEN TO A FILE, OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'
I>T
```

PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 01/21/81 TIME: 13:34:30

2. RESULTS
2.A.--HEADING

PROBLEM - ANCH2 - ANCHORED WALL DESIGN
LAYERED SOIL - GRANULAR BACKFILL - COHESIVE SUBSOIL
HORIZONTAL LINE LOAD AT TOP OF WALL

2.B.--SUMMARY OF RESULTS FOR ANCHORED WALL DESIGN

SOIL PRESSURES DETERMINED BY COULOMB
COEFFICIENTS AND THEORY OF ELASTICITY
EQUATIONS FOR SURCHARGE LOADS

METHOD	WALL PEN (FT)	BOTTOM ELEV (FT)	MAXIMUM BENDING MOMENT (LB-FT)	MAX SCALED DEFLECTION (LB-IN3)	ANCHOR FORCE (LB)
FREE EARTH :	3.2	-25.2	61315.	8.97E+09	8248.
FIXED EARTH:	10.4	-32.4	42644.	5.75E+09	6929.
EQUIV BEAM :	6.6	-28.6	53186.	6.30E+09	7695.
EQUAL MOM :	8.8	-30.8	41451.	5.39E+09	6838.
TERZAGHI :	8.7	-30.7	42342.	5.67E+09	6906.

(NOTE: PENETRATION FOR EQUIVALENT BEAM
METHOD DOES NOT INCLUDE INCREASE
PRESCRIBED BY DRAFT EM 1110-2-2906)

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

```
    DO YOU WANT COMPLETE RESULTS OUTPUT?
    ENTER 'YES' OR 'NO'
I>Y


    COMPLETE RESULTS ARE AVAILABLE FOR FOLLOWING
    METHODS OF ANALYSIS:
         FREE EARTH : ENTER 'FR' ON CUE
         FIXED EARTH: ENTER 'FI' ON CUE
         EQUIV BEAM : ENTER 'EB' ON CUE
         EQUAL MOM  : ENTER 'EM' ON CUE
         TERZAGHI   : ENTER 'TE' ON CUE


    ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED
I>FR
```

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY FREE EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
8.00	0.	-1000.	-3.70E+09	0.00
7.00	-1005.	-1016.	-2.78E+09	31.22
6.00	-2042.	-1062.	-1.86E+09	62.44
5.00	-3140.	-1140.	-9.32E+08	93.65
4.00	-4333.	-1250.	0.	124.87
4.00	-4333.	6998.	0.	124.87
3.00	2598.	6858.	9.37E+08	156.09
2.00	9372.	6686.	1.87E+09	187.31
1.00	15959.	6483.	2.79E+09	218.53
0.00	22328.	6249.	3.67E+09	249.74
-1.00	28438.	5958.	4.52E+09	331.87
-2.00	34217.	5585.	5.33E+09	413.99
-3.00	39581.	5130.	6.07E+09	496.11
-4.00	44449.	4593.	6.74E+09	578.23
-5.00	48750.	4005.	7.34E+09	597.86
-6.00	52453.	3397.	7.85E+09	617.48
-7.00	55538.	2770.	8.27E+09	637.10
-8.00	57986.	2123.	8.60E+09	656.73
-9.00	59778.	1457.	8.83E+09	676.35
-10.00	60893.	770.	8.95E+09	695.97
-11.00	61312.	65.	8.97E+09	715.59
-12.00	61015.	-661.	8.88E+09	735.22
-13.00	59984.	-1406.	8.68E+09	754.84
-14.00	58197.	-2171.	8.39E+09	774.46
-15.00	55636.	-2955.	7.99E+09	794.08
-16.00	52281.	-3759.	7.50E+09	813.71
-17.00	48112.	-4582.	6.91E+09	833.33
-18.00	43110.	-5425.	6.25E+09	852.95

-19.00	37255.	-6288.	5.51E+09	872.58
-20.00	30527.	-7170.	4.70E+09	892.20
-21.00	22907.	-8072.	3.84E+09	911.82
-22.00	14376.	-8994.	2.95E+09	931.44
-22.00	14376.	-8994.	2.95E+09	-2750.00
-23.00	6767.	-6214.	2.02E+09	-2810.00
-24.00	1967.	-3374.	1.09E+09	-2870.00
-25.00	38.	-474.	1.52E+08	-2930.00
-25.16	0.	-0.	0.	-2939.69

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'
I>Y

ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED
I>FI

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY FIXED EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
8.00	-0.	-1000.	-2.49E+09	0.00
7.00	-1005.	-1016.	-1.87E+09	31.22
6.00	-2042.	-1062.	-1.25E+09	62.44
5.00	-3140.	-1140.	-6.29E+08	93.65
4.00	-4333.	-1250.	0.	124.87
4.00	-4333.	5679.	0.	124.87
3.00	1279.	5539.	6.35E+08	156.09
2.00	6734.	5367.	1.27E+09	187.31
1.00	12002.	5164.	1.89E+09	218.53
0.00	17052.	4930.	2.49E+09	249.74
-1.00	21843.	4639.	3.06E+09	331.87
-2.00	26302.	4266.	3.59E+09	413.99
-3.00	30348.	3811.	4.08E+09	496.11
-4.00	33897.	3274.	4.51E+09	578.23
-5.00	36879.	2686.	4.89E+09	597.86
-6.00	39263.	2078.	5.20E+09	617.48
-7.00	41029.	1451.	5.45E+09	637.10
-8.00	42158.	804.	5.62E+09	656.73
-9.00	42630.	137.	5.73E+09	676.35
-9.20	42644.	0.	5.73E+09	680.33
-10.00	42426.	-549.	5.75E+09	695.97
-11.00	41526.	-1254.	5.71E+09	715.59
-12.00	39911.	-1980.	5.59E+09	735.22
-13.00	37560.	-2725.	5.41E+09	754.84
-14.00	34455.	-3490.	5.16E+09	774.46
-15.00	30575.	-4274.	4.85E+09	794.08
-16.00	25901.	-5078.	4.48E+09	813.71
-17.00	20413.	-5901.	4.08E+09	833.33
-18.00	14092.	-6744.	3.63E+09	852.95

-19.00	6917.	-7607.	3.17E+09	872.58
-20.00	-1129.	-8490.	2.69E+09	892.20
-21.00	-10068.	-9392.	2.21E+09	911.82
-22.00	-19919.	-10313.	1.75E+09	931.44
-22.00	-19919.	-10313.	1.75E+09	-2750.00
-23.00	-28847.	-7533.	1.33E+09	-2810.00
-24.00	-34965.	-4693.	9.55E+08	-2870.00
-25.00	-38213.	-1793.	6.40E+08	-2930.00
-26.00	-38531.	1167.	3.91E+08	-2990.00
-27.00	-35860.	4187.	2.08E+08	-3050.00
-27.87	-31027.	6876.	9.81E+07	-3102.46
-28.87	-22943.	8947.	2.23E+07	-1039.62
-29.38	-18346.	9209.	0.	0.00
-30.87	-5719.	6901.	-2.63E+07	3086.05
-31.87	-705.	2783.	-2.83E+07	5148.88
-32.37	0.	-0.	-2.83E+07	6163.98

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'
I>Y

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY EQUIV BEAM METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
8.00	-0.	-1000.	-2.82E+09	0.00
7.00	-1005.	-1016.	-2.12E+09	31.22
6.00	-2042.	-1062.	-1.42E+09	62.44
5.00	-3140.	-1140.	-7.11E+08	93.65
4.00	-4333.	-1250.	0.	124.87
4.00	-4333.	6445.	0.	124.87
3.00	2045.	6305.	7.16E+08	156.09
2.00	8266.	6133.	1.43E+09	187.31
1.00	14300.	5930.	2.13E+09	218.53
0.00	20116.	5696.	2.80E+09	249.74
-1.00	25673.	5405.	3.44E+09	331.87
-2.00	30899.	5032.	4.03E+09	413.99
-3.00	35711.	4577.	4.58E+09	496.11
-4.00	40026.	4040.	5.05E+09	578.23
-5.00	43774.	3452.	5.47E+09	597.86
-6.00	46924.	2844.	5.80E+09	617.48
-7.00	49456.	2217.	6.05E+09	637.10
-8.00	51351.	1570.	6.22E+09	656.73
-9.00	52590.	904.	6.30E+09	676.35
-10.00	53152.	217.	6.29E+09	695.97
-10.31	53186.	0.	6.26E+09	702.07
-11.00	53018.	-488.	6.19E+09	715.59
-12.00	52169.	-1214.	5.99E+09	735.22
-13.00	50584.	-1959.	5.71E+09	754.84
-14.00	48245.	-2723.	5.34E+09	774.46
-15.00	45131.	-3508.	4.88E+09	794.08
-16.00	41223.	-4312.	4.35E+09	813.71
-17.00	36501.	-5135.	3.75E+09	833.33
-18.00	30946.	-5978.	3.08E+09	852.95

-19.00	24538.	-6841.	2.36E+09	872.58
-20.00	17257.	-7723.	1.60E+09	892.20
-21.00	9085.	-8625.	8.08E+08	911.82
-22.00	-0.	-9547.	0.	931.44

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

(NOTE: OUTPUT TABLE FOR EQUIVALENT BEAM
METHOD ENDS AT ASSUMED POINT OF INFLECTION)

DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'

I>Y

ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY EQUAL MOM METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
8.00	0.	-1000.	-2.37E+09	0.00
7.00	-1005.	-1016.	-1.78E+09	31.22
6.00	-2042.	-1062.	-1.19E+09	62.44
5.00	-3140.	-1140.	-5.98E+08	93.65
4.00	-4333.	-1250.	0.	124.87
4.00	-4333.	5588.	0.	124.87
3.00	1188.	5448.	6.04E+08	156.09
2.00	6552.	5276.	1.21E+09	187.31
1.00	11730.	5073.	1.80E+09	218.53
0.00	16688.	4839.	2.37E+09	249.74
-1.00	21389.	4548.	2.91E+09	331.87
-2.00	25758.	4175.	3.41E+09	413.99
-3.00	29712.	3720.	3.87E+09	496.11
-4.00	33171.	3183.	4.28E+09	578.23
-5.00	36062.	2595.	4.63E+09	597.86
-6.00	38354.	1987.	4.92E+09	617.48
-7.00	40030.	1360.	5.15E+09	637.10
-8.00	41068.	713.	5.30E+09	656.73
-9.00	41450.	47.	5.38E+09	676.35
-10.00	41155.	-639.	5.39E+09	695.97
-11.00	40164.	-1345.	5.34E+09	715.59
-12.00	38458.	-2071.	5.21E+09	735.22
-13.00	36016.	-2816.	5.01E+09	754.84
-14.00	32820.	-3580.	4.75E+09	774.46
-15.00	28849.	-4365.	4.44E+09	794.08
-16.00	24084.	-5169.	4.08E+09	813.71
-17.00	18506.	-5992.	3.67E+09	833.33
-18.00	12094.	-6835.	3.24E+09	852.95

-19.00	4829.	-7698.	2.78E+09	872.58
-20.00	-3309.	-8580.	2.31E+09	892.20
-21.00	-12338.	-9482.	1.85E+09	911.82
-22.00	-22280.	-10404.	1.41E+09	931.44
-22.00	-22280.	-10404.	1.41E+09	-2750.00
-23.00	-31299.	-7624.	1.01E+09	-2810.00
-24.00	-37508.	-4784.	6.67E+08	-2870.00
-25.00	-40847.	-1884.	3.85E+08	-2930.00
-26.00	-41256.	1076.	1.73E+08	-2990.00
-27.00	-38675.	4096.	3.24E+07	-3050.00
-28.00	-33044.	7176.	-4.23E+07	-3110.00
-29.00	-24303.	10316.	-6.02E+07	-3170.00
-30.00	-12392.	13516.	-3.67E+07	-3230.00
-30.83	-0.	16229.	0.	-3280.00

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'

I>Y
ENTER METHOD FOR WHICH COMPLETE RESULTS ARE DESIRED
I>TE

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY TERZAGHI METHOD

I

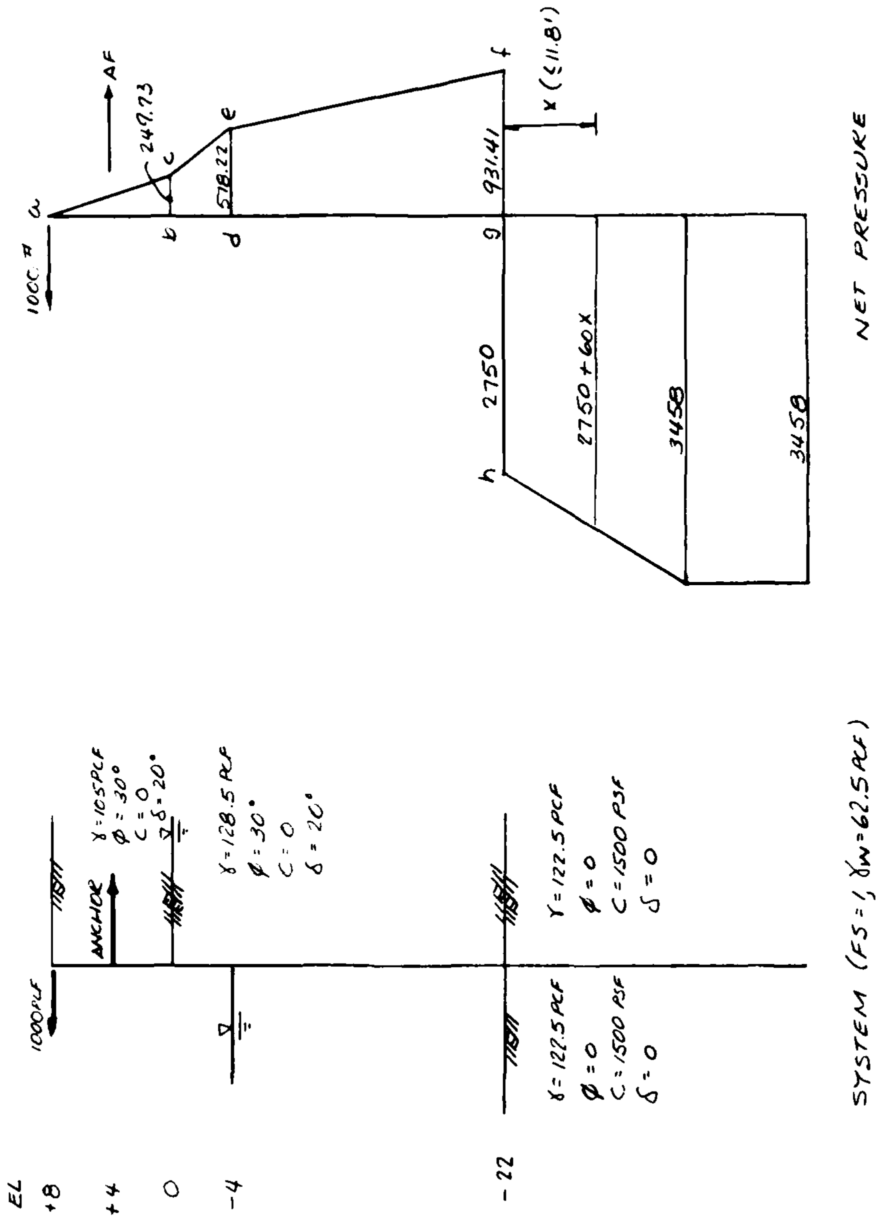
ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
8.00	-0.	-1000.	-2.46E+09	0.00
7.00	-1005.	-1016.	-1.85E+09	31.22
6.00	-2042.	-1062.	-1.24E+09	62.44
5.00	-3140.	-1140.	-6.22E+08	93.65
4.00	-4333.	-1250.	0.	124.87
4.00	-4333.	5656.	0.	124.87
3.00	1256.	5516.	6.28E+08	156.09
2.00	6688.	5344.	1.25E+09	187.31
1.00	11933.	5141.	1.87E+09	218.53
0.00	16960.	4907.	2.46E+09	249.74
-1.00	21728.	4616.	3.02E+09	331.87
-2.00	26165.	4243.	3.55E+09	413.99
-3.00	30187.	3788.	4.03E+09	496.11
-4.00	33714.	3251.	4.46E+09	578.23
-5.00	36672.	2663.	4.83E+09	597.86
-6.00	39033.	2055.	5.14E+09	617.48
-7.00	40776.	1428.	5.38E+09	637.10
-8.00	41882.	781.	5.55E+09	656.73
-9.00	42332.	115.	5.65E+09	676.35
-9.17	42342.	0.	5.65E+09	679.66
-10.00	42105.	-572.	5.67E+09	695.97
-11.00	41182.	-1277.	5.62E+09	715.59
-12.00	39544.	-2003.	5.51E+09	735.22
-13.00	37170.	-2748.	5.32E+09	754.84
-14.00	34041.	-3512.	5.07E+09	774.46
-15.00	30138.	-4297.	4.76E+09	794.08
-16.00	25441.	-5101.	4.40E+09	813.71
-17.00	19931.	-5924.	3.99E+09	833.33
-18.00	13586.	-6767.	3.55E+09	852.95

-19.00	6389.	-7630.	3.09E+09	872.58
-20.00	-1680.	-8512.	2.61E+09	892.20
-21.00	-10642.	-9414.	2.14E+09	911.82
-22.00	-20516.	-10336.	1.69E+09	931.44
-22.00	-20516.	-10336.	1.69E+09	-2750.00
-23.00	-29467.	-7556.	1.27E+09	-2810.00
-24.00	-35608.	-4716.	9.02E+08	-2870.00
-25.00	-38879.	-1816.	5.96E+08	-2930.00
-26.00	-39220.	1144.	3.57E+08	-2990.00
-27.00	-36571.	4164.	1.85E+08	-3050.00
-28.00	-30872.	7244.	7.61E+07	-3110.00
-29.00	-22064.	10384.	1.99E+07	-3170.00
-30.00	-10085.	13584.	1.42E+06	-3230.00
-30.69	-0.	15814.	0.	-3271.17

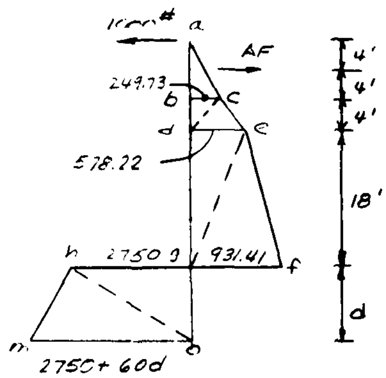
(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

```
     DO YOU WANT RESULTS FOR ANOTHER METHOD? ENTER 'YES' OR 'NO'
I>N
     DO YOU WANT GEOMETRY AND/OR RESULTS PLOTTED?
     ENTER 'GEOMETRY', 'RESULTS', 'BOTH', OR 'NEITHER'
I>N
     OUTPUT COMPLETE
```

Verification of Problem "ANCH2" (Sheet 1 of 7)



FREE EARTH METHOD: (ASSUME $d < 11.8'$)



FORCE	PRESS LINE	FACTORS	MOMENT ARM ABOUT AF	MOMENT ABOUT AF
P1	LINE LOAD	1000.00	−4.00	−4000
P2	abc	249.73(8)/2 = 998.92	2/3(8) − 4 = 1.33	1328.56
P3	bcd	249.73(4)/2 = 499.46	4/3 + 4 = 5.33	2662.12
P4	cde	578.22(4)/2 = 1156.44	2/3(4) + 4 = 6.67	7713.45
P5	def	578.22(18)/2 = 5203.98	4 + 4 + 18/3 = 14.00	72855.72
P6	efg	931.41(18)/2 = 8382.69	4 + 4 + 2/3(18) = 20.00	167653.80
P7	gho	−2750.00(d)/2 = −1375.00d	26 + 0.33d	−35750.00d − 453.75d²
P8	hmo	−(2750 + 60d)(d)/2 = −1375.00d − 30.00d²	26 + 0.67d	−35750.00d −1701.25d² − 20.10d³
P9	AF	−AF	0	0

$\Sigma F_H = \Sigma P = 17241.49 - 2750.00d - 30d^2 - AF$

$\Sigma M_{AF} = 248213.65 - 71500.00d - 2155.00d^2 - 20.1d^3$

$\Sigma M_{AF} = 0$

TRIAL d	ΣM_{AF}
2'	96433
3'	13776
4'	−73553

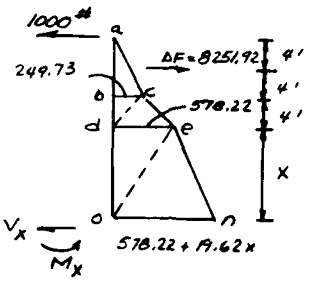
INTERPOLATE $d = 3 + 13776/(13776 + 73553) = 3.16$

3.16	120	SAY OK

(PROGRAM $d = 3.21'$)

FOR $\Sigma F_H = 0$ AF = 8251.92 (PROGRAM 8111#)

MAXIMUM MOMENT FOR FREE EARTH METHOD.
MAXIMUM OCCURS BETWEEN POINTS d AND g



FORCE	PRESS DIAG	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	LINE LOAD	1000.00	12.00 + X	12000.00 + 1000.00X
P2	abc	998.92	5.33 + X	5324.24 + 998.92X
P3	bcd	499.46	2.67 + X	1333.56 + 499.46X
P3	cde	1156.44	1.33 + X	1538.07 + 1156.44X
P4	deo	578.22 (x)/2 = 289.11 X	0.67X	193.70 x^2
P5	eon	(578.22 + 19.62x)(x)/2 = 289.11 X + 9.81 X^2	0.33 X	95.41 X^2 + 3.24 X^3
P6	ΔF	− 8251.92	8 + X	− 66015.36 − 8251.92X

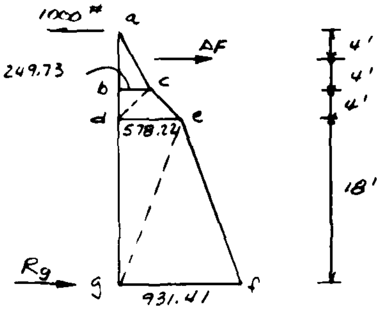
$$\Sigma F_H = -V_x = -4597.10 + 578.22x + 9.81x^2$$

$$\Sigma M_H = -M_x = -45819.49 - 4597.10x + 289.11x^2 + 3.24x^3$$

FOR $V_x = 0$ $\quad X = 7.10$

$M_{MAX} = M_x = 62725$ #' (PROGRAM 61177 #')

DESIGN BY EQUIVALENT BEAM METHOD WITH
POINT OF INFLECTION AT POINT g



FORCE	PRESS DIAG	FACTORS		MOMENT ARM ABOUT AF	MOMENT ABOUT AF
P1	LINE LOAD		1000.00	-4.00	-4000.00
P2	abc		998.92	1.33	1328.56
P3	bcd		499.46	5.33	2662.12
P4	cde		1156.44	6.67	7713.45
P5	def		5203.98	14.00	72855.72
P6	efg		8382.69	20.00	167653.80
P7	AF		-AF	0	0
P8	Rg		-Rg	26.00	-26.00 Rg

$\Sigma F_H = 17241.49 - AF - Rg$

$\Sigma M_{AF} = 248213.65 - 26.00\,Rg$

$\Sigma M_{AF} = 0 \qquad Rg = 9546.68$

$\Sigma F_H = 0 \qquad AF = 7694.81$ (PROGRAM 7541)

FOR MAXIMUM BENDING MOMENT (FROM FREE EARTH METHOD WITH AF = 7694.81)

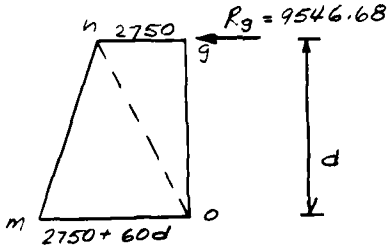
$-V_0 = -4039.99 + 578.22X + 9.81X^2 = 0$

OR $X = 6.31$

$M_0 = M_{MAX} = 41362.61 + 4039.99X - 298.11X^2 - 3.24X^3$

OR $M_{MAX} = 54171$ #' (PROGRAM 53155 #')

PENETRATION BY EQUIVALENT BEAM METHOD
ASSUME $d < 11.80'$

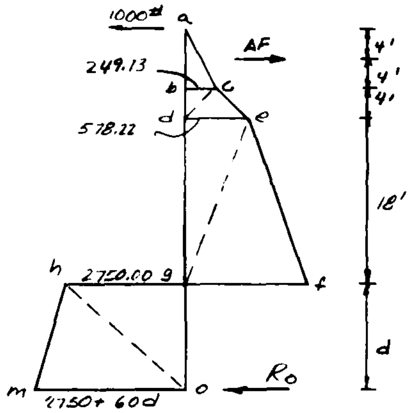


FORCE	PRESS DIAG.	FACTORS	MOMENT ARM ABOUT O	MOMENT ABOUT O
P1	gho	$-2750(d)/2 = -1375.00d$	$0.67d$	$-921.25d^2$
P2	hmo	$-(2750+60d)(d)/2 = -1375.00d - 30.00d^2$	$0.33d$	$-453.75d^2 - 9.90d^3$
P3	R_g	9546.68	d	$9546.68d$

$$\Sigma M_o = 9546.68d - 1375.00d^2 - 9.90d^3 = 0$$

$d = 6.63'$ (PROGRAM $6.7'$)

DESIGN BY EQUAL MOMENT METHOD (ASSUME $d < 11.8'$)



FROM FREE EARTH METHOD

(1) $\Sigma F_H = 17241.49 - 2750.00d - 30.00d^2 - AF + R_o = 0$

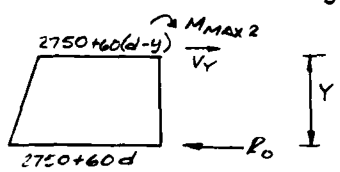
(2) $\Sigma M_{AF} = 248213.65 - 71500.00d - 2155.00d^2 - 20.1d^3 + (26.00 + x)R_o = 0$

MAXIMUM MOMENT ABOVE g (FROM FREE EARTH METHOD)

(3) $V_x = AF - 3654.82 - 578.22x + 9.81x^2 = 0$

(4) $M_x = M_{MAX1} = -20195.87 + AF(8+x) - 3654.82x - 289.11x^2 - 3.24x^3$

FOR MAXIMUM MOMENT BELOW g



$V_Y = 0 = -(2750.00 + 60.00d)Y/2 - [2750.00 + 60.00(d-Y)]Y/2 + R_o$

(5) OR $30.00Y^2 - (2750.00 + 60.00d)Y + R_o = 0$

(6) $M_{MAX2} = -(1375.00 + 30.00d - 20.00Y)Y^2$

PROCEDURE FOR DETERMINATION OF PENETRATION FOR EQUAL MOMENT METHOD

1. ASSUME d
2. CALCULATE R_o FROM EQN (2)
3. CALCULATE AF FROM (1)
4. CALCULATE X FROM (3)
5. CALCULATE M_{MAX1} FROM (4)
6. CALCULATE Y FROM (5)
7. CALCULATE M_{MAX2} FROM (6)
8. REPEAT UNTIL $|M_{MAX1}| = |M_{MAX2}|$

TRIAL d	R_O	A_F	X	M_{MAX1}	Y	M_{MAX2}	$M_{MAX1}+M_{MAX2}$
7	11053.81	7574.27	6.14	52814	3.61	-19715	33099
8	13882.28	7203.77	5.60	47673	4.48	-30615	17058
9	16699.84	6761.33	4.96	41795	5.34	-43863	-2068
8.89	16390.30	6813.33	5.03	42471	5.24	-42200	271
8.90	16418.45	6808.64	5.03	42410	5.25	-42364	46 OK

(PROGRAM d = 8.84', AF = 6834#, M_{MAX} = 41584#')

PROBLEM "ANCH3"

Anchored Wall Design--Granular Soil With Seepage Effects

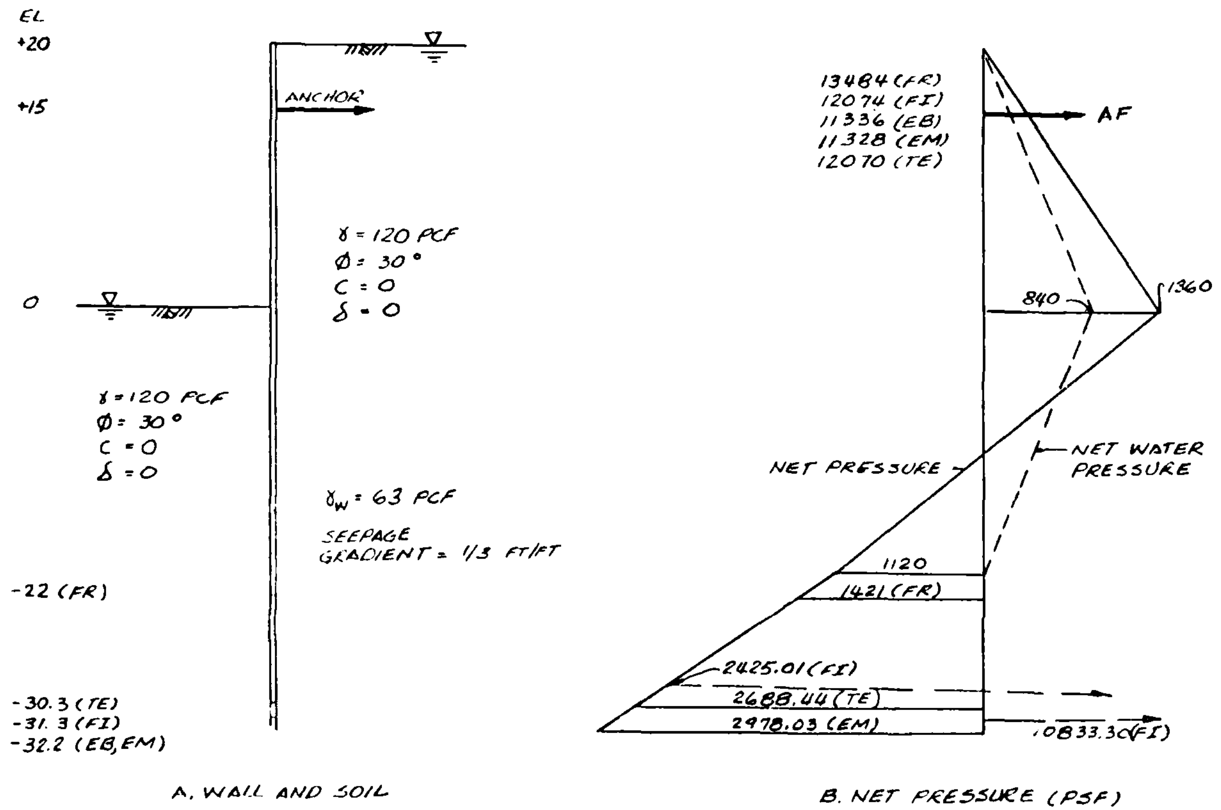


Figure C3. System and program results for problem "ANCH3"

AD-A098 693   OKLAHOMA STATE UNIV STILLWATER DEPT OF CIVIL ENGINEERING   F/G 13/13
USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET--ETC(U)
FEB 81   W P DAWKINS   DACW39-79-M-1229

UNCLASSIFIED   WES-INSTRUCTION-K-81-2-1   NL

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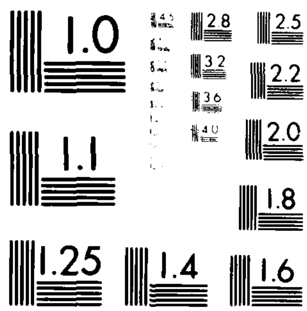

MICROCOPY RESOLUTION TEST CHART

```
1000 3 PROBLEM - ANCH3 - ANCHORED WALL DESIGN
1010 SEEPAGE GRADIENT = 1/3
1020 ZERO NET HORIZONTAL WATER PRESSURE AT EL -20
1030 A D 5
1040 20 15 1
1050 1 1
1060 20
1070 120 30 0 0
1080 1 1
1090 0
1100 120 30 0 0
1110 20 0 63 .3333
1120 0 N
1130 0 0 0
```

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PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 10/15/80                        TIME: 17:54:39

I. INPUT DATA

I.A.--HEADING

PROBLEM - ANCH3 - ANCHORED WALL DESIGN
SEEPAGE GRADIENT = 1/3
ZERO NET HORIZONTAL WATER PRESSURE AT EL -20


I.B.--WALL TYPE, MODE, METHOD
     ANCHORED WALL DESIGN   BY FREE EARTH METHOD
     ANCHORED WALL DESIGN   BY FIXED EARTH METHOD
     ANCHORED WALL DESIGN   BY EQUIVALENT BEAM METHOD
     ANCHORED WALL DESIGN   BY EQUAL MOMENT METHOD
     ANCHORED WALL DESIGN   BY TERZAGHI METHOD


I.C.--WALL DESCRIPTION
     TOP OF WALL ELEVATION =   20.00 (FT)
     ANCHOR ELEVATION      =   15.00 (FT)
     FACTOR OF SAFETY      =    1.00


I.D.--RIGHT SIDE SOIL DESCRIPTION
     NUMBER OF RIGHT SIDE SURFACE POINTS =  1
     NUMBER OF RIGHT SIDE SOIL LAYERS    =  1


     RIGHT SIDE SURFACE POINT COORDINATES
     POINT       ELEVATION       X-COORD
      NO.          (FT)           (FT)
       1           20.00          0.00


RIGHT SIDE SOIL LAYER DATA
                    INTERNAL                      WALL      BOTTOM
LAYER     UNIT      FRICTION                    FRICTION     ELEV       BOTTOM
 NO.     WEIGHT      ANGLE      COHESION         ANGLE      AT WALL     SLOPE
          (PCF)      (DEG)       (PSF)           (DEG)       (FT)      (FT/FT)
  1      120.00      30.00        0.00            0.00
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1.E.--LEFT SIDE SOIL DESCRIPTION
     NUMBER OF LEFT SIDE SURFACE POINTS     =  1
     NUMBER OF LEFT SIDE SOIL LAYERS        =  1


     LEFT SIDE SURFACE POINT COORDINATES
     POINT       ELEVATION       X-COORD
      NO.          (FT)           (FT)
       1           0.00           0.00

LEFT  SIDE SOIL LAYER DATA
                 INTERNAL                    WALL      BOTTOM
LAYER    UNIT    FRICTION                  FRICTION     ELEV       BOTTOM
 NO.    WEIGHT    ANGLE      COHESION       ANGLE     AT WALL      SLOPE
         (PCF)    (DEG)       (PSF)         (DEG)       (FT)      (FT/FT)
   1    120.00    30.00       0.00          0.00

1.F.--WATER DATA
     RIGHT SIDE ELEVATION           =    20.00 (FT)
     LEFT SIDE ELEVATION            =     0.00 (FT)
     WATER UNIT WEIGHT              =    63.00 (PCF)
     SEEPAGE GRADIENT               =      .33 (FT/FT)

1.G.--SURCHARGE LOADS
     NUMBER OF LINE LOADS               =  0
     DISTRIBUTED LOAD DISTRIBUTION = NONE

1.H.--HORIZONTAL LOADS
     NUMBER OF HORIZONTAL LINE LOADS              =    0
     NUMBER OF HORIZONTAL PRESSURE POINTS         =    0
     EARTHQUAKE ACCELERATION                      =    0.00 (G'S)
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PROGRAM SHTWAL - DESIGN/ANALYSIS OF ANCHORED
OR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS
DATE: 10/15/80 TIME: 17:55:09

2. RESULTS

2.A.--HEADING

PROBLEM - ANCH3 - ANCHORED WALL DESIGN
SEEPAGE GRADIENT - 1/3
ZERO NET HORIZONTAL WATER PRESSURE AT EL -20

2.B.- SUMMARY OF RESULTS FOR ANCHORED WALL DESIGN

SOIL PRESSURES DETERMINED BY COULOMB
COEFFICIENTS AND THEORY OF ELASTICITY
EQUATIONS FOR SURCHARGE LOADS

METHOD	WALL PEN (FT)	BOTTOM ELEV (FT)	MAXIMUM BENDING MOMENT (LB-FT)	MAX SCALED DEFLECTION (LB-IN3)	ANCHOR FORCE (LB)
FREE EARTH :	22.0	-22.0	111593.	2.41E+10	13484.
FIXED EARTH:	31.3	-31.3	91317.	1.75E+10	12074.
EQUIV BEAM :	32.2	-32.2	81310.	9.55E+09	11336.
EQUAL MOM :	32.2	-32.2	81263.	1.11E+10	11328.
TERZAGHI :	30.3	-30.3	91254.	1.75E+10	12070.

(NOTE: PENETRATION FOR EQUIVALENT BEAM
METHOD DOES NOT INCLUDE INCREASE
PRESCRIBED BY DRAFT EM 1110-2-2906)

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

2.C.- COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY FREE EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	-0.	0.	-1.12E+10	0.00
19.00	-11.	-34.	-8.97E+09	68.00
18.00	-91.	-136.	-6.73E+09	136.00
17.00	-306.	-306.	-4.49E+09	204.00
16.00	-725.	-544.	-2.24E+09	272.01
15.00	-1417.	-850.	0.	340.01
15.00	-1417.	12634.	0.	340.01
14.00	11036.	12260.	2.24E+09	408.01
13.00	23080.	11818.	4.47E+09	476.01
12.00	34649.	11308.	6.65E+09	544.01
11.00	45673.	10730.	8.77E+09	612.01
10.00	56085.	10084.	1.08E+10	680.01
9.00	65818.	9370.	1.28E+10	748.02
8.00	74802.	8588.	1.46E+10	816.02
7.00	82970.	7738.	1.63E+10	884.02
6.00	90255.	6820.	1.79E+10	952.02
5.00	96587.	5834.	1.93E+10	1020.02
4.00	101899.	4780.	2.05E+10	1088.02
3.00	106124.	3658.	2.16E+10	1156.02
2.00	109192.	2468.	2.25E+10	1224.03
1.00	111036.	1210.	2.32E+10	1292.03
0.00	111588.	-116.	2.37E+10	1360.03
-1.00	110812.	-1415.	2.40E+10	1236.03
-2.00	108800.	-2589.	2.41E+10	1112.02
-3.00	105676.	-3639.	2.40E+10	988.02
-4.00	101565.	-4565.	2.37E+10	864.02
-5.00	96509.	-5367.	2.33E+10	740.01
-6.00	90873.	-6045.	2.27E+10	616.01
-7.00	84541.	-6599.	2.20E+10	492.01
-8.00	77717.	-7029.	2.11E+10	368.01
-9.00	70525.	-7335.	2.00E+10	244.00
-10.97	55777.	-7575.	1.77E+10	0.00

-11.00	55533.	-7575.	1.76E+10	-4.00
-12.00	47981.	-7509.	1.63E+10	-128.01
-13.00	40557.	-7319.	1.48E+10	-252.01
-14.00	33385.	-7005.	1.33E+10	-376.01
-15.00	26589.	-6567.	1.17E+10	-500.01
-16.00	20293.	-6005.	1.01E+10	-624.02
-17.00	14621.	-5319.	8.46E+09	-748.02
-18.00	9698.	-4509.	6.78E+09	-872.02
-19.00	5646.	-3575.	5.09E+09	-996.03
-20.00	2590.	-2516.	3.39E+09	-1120.27
-20.00	2590.	-2516.	3.39E+09	-1120.40
-21.00	659.	-1320.	1.68E+09	-1271.94
-21.98	0.	-0.	0.	-1420.98

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY FIXED EARTH METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	0.	0.	-8.68E+09	0.00
19.00	-11.	-34.	-6.94E+09	68.00
18.00	-91.	-136.	-5.21E+09	136.00
17.00	-306.	-306.	-3.47E+09	204.00
16.00	-725.	-544.	-1.74E+09	272.01
15.00	-1417.	-850.	0.	340.01
15.00	-1417.	11224.	0.	340.01
14.00	9626.	10850.	1.74E+09	408.01
13.00	20261.	10408.	3.46E+09	476.01
12.00	30420.	9898.	5.14E+09	544.01
11.00	40034.	9320.	6.77E+09	612.01
10.00	49037.	8674.	8.34E+09	680.01
9.00	57360.	7960.	9.81E+09	748.02
8.00	64935.	7178.	1.12E+10	816.02
7.00	71693.	6328.	1.25E+10	884.02
6.00	77568.	5410.	1.36E+10	952.02
5.00	82491.	4424.	1.46E+10	1020.02
4.00	86393.	3370.	1.55E+10	1088.02
3.00	89208.	2248.	1.62E+10	1156.02
2.00	90867.	1058.	1.68E+10	1224.03
1.16	91317.	0.	1.71E+10	1281.45
1.00	91301.	-200.	1.72E+10	1292.03
0.00	90444.	-1526.	1.74E+10	1360.03
-1.00	88258.	-2824.	1.75E+10	1236.03
-2.00	84837.	-3998.	1.75E+10	1112.02
-3.00	80303.	-5048.	1.73E+10	988.02
-4.00	74782.	-5974.	1.69E+10	864.02
-5.00	68396.	-6776.	1.64E+10	740.01
-6.00	61271.	-7454.	1.58E+10	616.01
-7.00	53529.	-8008.	1.51E+10	492.01
-8.00	45296.	-8438.	1.44E+10	368.01
-9.00	36694.	-8744.	1.35E+10	244.00
-10.00	27848.	-8926.	1.26E+10	120.00
-10.97	19173.	-8984.	1.16E+10	0.00

-12.00	9921.	-8918.	1.06E+10	-128.01
-13.00	1088.	-8728.	9.54E+09	-252.01
-14.00	-7494.	-8414.	8.51E+09	-376.01
-15.00	-15700.	-7976.	7.50E+09	-500.01
-16.00	-23405.	-7414.	6.50E+09	-624.02
-17.00	-30487.	-6728.	5.55E+09	-748.02
-18.00	-36820.	-5918.	4.66E+09	-872.02
-19.00	-42282.	-4984.	3.82E+09	-996.03
-20.00	-46747.	-3926.	3.06E+09	-1120.27
-20.00	-46747.	-3926.	3.06E+09	-1120.40
-21.00	-50088.	-2730.	2.38E+09	-1271.94
-22.00	-52156.	-1382.	1.79E+09	-1423.94
-23.00	-52801.	118.	1.28E+09	-1575.94
-24.00	-51869.	1770.	8.70E+08	-1727.94
-25.00	-49210.	3574.	5.46E+08	-1879.94
-26.00	-44671.	5530.	3.07E+08	-2031.94
-27.00	-38100.	7638.	1.45E+08	-2183.94
-28.00	-29345.	9898.	4.83E+07	-2335.94
-28.59	-23138.	11293.	1.62E+07	-2425.01
-29.08	-17395.	11888.	0.	0.00
-30.59	-2284.	6271.	-1.43E+07	7446.80
-31.27	-0.	-0.	-1.45E+07	10833.30

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY EQUIV BEAM METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	-0.	0.	-5.73E+09	0.00
19.00	-11.	-34.	-4.58E+09	68.00
18.00	-91.	-136.	-3.44E+09	136.00
17.00	-306.	-306.	-2.29E+09	204.00
16.00	-725.	-544.	-1.15E+09	272.01
15.00	-1417.	-850.	0.	340.01
15.00	-1417.	10486.	0.	340.01
14.00	8088.	10112.	1.15E+09	408.01
13.00	18784.	9670.	2.28E+09	476.01
12.00	28205.	9160.	3.37E+09	544.01
11.00	37081.	8582.	4.42E+09	612.01
10.00	45346.	7936.	5.41E+09	680.01
9.00	52930.	7222.	6.32E+09	748.02
8.00	59766.	6440.	7.13E+09	816.02
7.00	65787.	5590.	7.85E+09	884.02
6.00	70923.	4672.	8.44E+09	952.02
5.00	75107.	3686.	8.92E+09	1020.02
4.00	78272.	2632.	9.27E+09	1088.02
3.00	80348.	1510.	9.48E+09	1156.02
2.00	81268.	320.	9.55E+09	1224.03
1.74	81310.	0.	9.54E+09	1241.65
1.00	80965.	-938.	9.49E+09	1292.03
0.00	79369.	-2264.	9.28E+09	1360.03
-1.00	76445.	-3562.	8.94E+09	1236.03
-2.00	72285.	-4737.	8.46E+09	1112.02
-3.00	67013.	-5787.	7.86E+09	988.02
-4.00	60754.	-6713.	7.14E+09	864.02
-5.00	53630.	-7515.	6.32E+09	740.01
-6.00	45766.	-8193.	5.41E+09	616.01
-7.00	37286.	-8747.	4.42E+09	492.01
-8.00	28314.	-9177.	3.36E+09	368.01
-9.00	18974.	-9483.	2.26E+09	244.00
-10.97	-0.	-9723.	0.	0.00

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)
(NOTE: OUTPUT TABLE FOR EQUIVALENT BEAM
METHOD ENDS AT ASSUMED POINT OF INFLECTION)

2.C.--COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY EQUAL MOM METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	-0.	0.	-6.29E+09	0.00
19.00	-11.	-34.	-5.03E+09	68.00
18.00	-91.	-136.	-3.78E+09	136.00
17.00	-306.	-306.	-2.52E+09	204.00
16.00	-725.	-544.	-1.26E+09	272.01
15.00	-1417.	-850.	0.	340.01
15.00	-1417.	10478.	0.	340.01
14.00	8880.	10104.	1.26E+09	408.01
13.00	18769.	9662.	2.50E+09	476.01
12.00	28182.	9152.	3.71E+09	544.01
11.00	37051.	8574.	4.88E+09	612.01
10.00	45308.	7928.	5.97E+09	680.01
9.00	52885.	7214.	6.99E+09	748.02
8.00	59714.	6432.	7.92E+09	816.02
7.00	65727.	5582.	8.75E+09	884.02
6.00	70856.	4664.	9.46E+09	952.02
5.00	75033.	3678.	1.01E+10	1020.02
4.00	78190.	2624.	1.05E+10	1088.02
3.00	80259.	1502.	1.08E+10	1156.02
2.00	81172.	312.	1.10E+10	1224.03
1.00	80861.	-946.	1.11E+10	1292.03
0.00	79257.	-2272.	1.10E+10	1360.03
-1.00	76326.	-3570.	1.08E+10	1236.03
-2.00	72159.	-4744.	1.04E+10	1112.02
-3.00	66880.	-5794.	9.91E+09	988.02
-4.00	60612.	-6720.	9.31E+09	864.02
-5.00	53481.	-7522.	8.60E+09	740.01
-6.00	45610.	-8200.	7.80E+09	616.01
-7.00	37122.	-8754.	6.93E+09	492.01
-8.00	28143.	-9184.	5.99E+09	368.01
-9.00	18796.	-9490.	5.00E+09	244.00
-10.97	-193.	-9730.	2.97E+09	0.00

-11.00	507.	-9730.	2.94E+09	-4.00
-12.00	-10214.	-9664.	1.90E+09	-128.01
-13.00	-19794.	-9474.	8.82E+08	-252.01
-14.00	-29121.	-9160.	-1.02E+08	-376.01
-15.00	-38072.	-8722.	-1.04E+09	-500.01
-16.00	-46524.	-8160.	-1.91E+09	-624.02
-17.00	-54351.	-7474.	-2.69E+09	-748.02
-18.00	-61430.	-6664.	-3.39E+09	-872.02
-19.00	-67638.	-5730.	-3.98E+09	-996.03
-20.00	-72849.	-4672.	-4.45E+09	-1120.27
-20.00	-72849.	-4672.	-4.45E+09	-1120.40
-21.00	-76935.	-3476.	-4.80E+09	-1271.94
-22.00	-79749.	-2128.	-5.01E+09	-1423.94
-23.00	-81140.	-628.	-5.08E+09	-1575.94
-23.39	-81263.	0.	-5.06E+09	-1635.37
-24.00	-80954.	1024.	-5.02E+09	-1727.94
-25.00	-79041.	2828.	-4.82E+09	-1879.94
-26.00	-75247.	4784.	-4.48E+09	-2031.94
-27.00	-69422.	6092.	-4.01E+09	-2183.94
-28.00	-61412.	9152.	-3.42E+09	-2335.94
-29.00	-51067.	11564.	-2.72E+09	-2487.94
-30.00	-38234.	14128.	-1.94E+09	-2639.94
-31.00	-22760.	16844.	-1.09E+09	-2791.94
-32.00	-4495.	19712.	-2.01E+08	-2943.94
-32.22	0.	20376.	0.	-2978.03

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

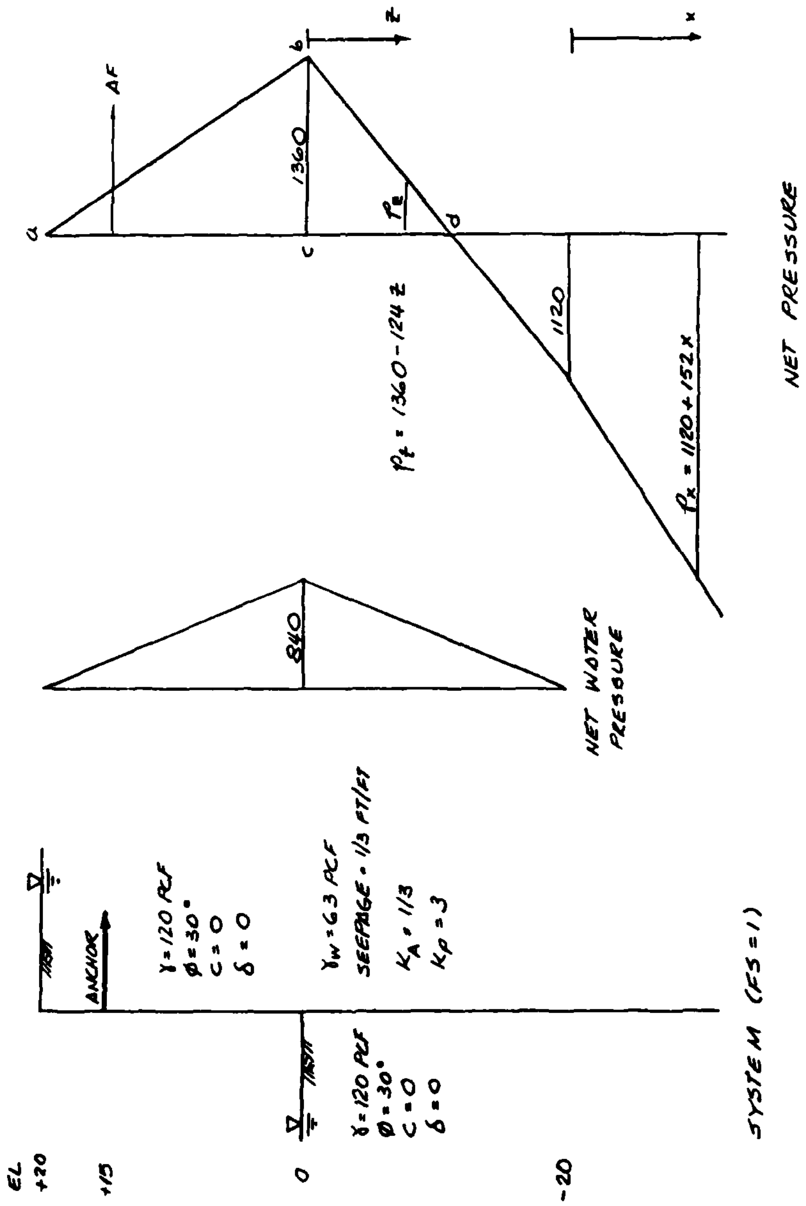
2.C. COMPLETE RESULTS FOR ANCHORED WALL DESIGN
BY TERZAGHI METHOD

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	0.	0.	-8.67E+09	0.00
19.00	-11.	-34.	-6.93E+09	68.00
18.00	-91.	-136.	-5.20E+09	136.00
17.00	-306.	-306.	-3.47E+09	204.00
16.00	-725.	-544.	-1.73E+09	272.01
15.00	-1417.	-850.	0.	340.01
15.00	-1417.	11220.	0.	340.01
14.00	9622.	10846.	1.73E+09	408.01
13.00	20252.	10404.	3.45E+09	476.01
12.00	30406.	9894.	5.13E+09	544.01
11.00	40016.	9316.	6.76E+09	612.01
10.00	49014.	8670.	8.32E+09	680.01
9.00	57333.	7956.	9.80E+09	748.02
8.00	64903.	7174.	1.12E+10	816.02
7.00	71657.	6323.	1.24E+10	884.02
6.00	77527.	5405.	1.36E+10	952.02
5.00	82445.	4419.	1.46E+10	1020.02
4.00	86343.	3365.	1.55E+10	1088.02
3.00	89153.	2243.	1.62E+10	1156.02
2.00	90807.	1053.	1.67E+10	1224.03
1.16	91254.	0.	1.71E+10	1281.21
1.00	91237.	-205.	1.71E+10	1292.03
0.00	90375.	-1531.	1.74E+10	1360.03
-1.00	88185.	-2829.	1.75E+10	1236.03
-2.00	84759.	-4003.	1.74E+10	1112.02
-3.00	80221.	-5053.	1.72E+10	988.02
-4.00	74695.	-5979.	1.69E+10	864.02
-5.00	68305.	-6781.	1.64E+10	740.01
-6.00	61175.	-7459.	1.58E+10	616.01
-7.00	53429.	-8013.	1.51E+10	492.01
-8.00	45191.	-8443.	1.43E+10	368.01
-9.00	36584.	-8749.	1.35E+10	244.00
-10.97	19054.	-8989.	1.16E+10	0.00

-11.00	18764.	8989.	1.15E+10	-4.00
12.00	9798.	-8923.	1.05E+10	-128.01
13.00	960.	-8733.	9.51E+09	-252.01
14.00	-7626.	8419.	8.48E+09	-376.01
-15.00	-15836.	7981.	7.46E+09	-500.01
16.00	-23546.	7419.	6.47E+09	624.02
-17.00	30632.	6733.	5.52E+09	-748.02
18.00	36971.	-5923.	4.63E+09	-872.02
19.00	-42437.	-4989.	3.79E+09	-996.03
20.00	46907.	-3931.	3.04E+09	-1120.27
20.00	46907.	-3931.	3.04E+09	-1120.40
21.00	-50252.	-2734.	2.36E+09	-1271.94
22.00	52325.	-1386.	1.77E+09	-1423.94
-23.00	52974.	114.	1.27E+09	-1575.94
24.00	-52047.	1765.	8.56E+08	-1727.94
-25.00	-49392.	3569.	5.36E+08	-1879.94
26.00	-44857.	5525.	3.01E+08	-2031.94
27.00	-38291.	7633.	1.43E+08	-2183.94
-28.00	-29540.	9893.	5.10E+07	-2335.94
29.00	18454.	12305.	9.80E+06	-2487.94
-30.00	4879.	14869.	1.43E+05	-2639.94
-30.32	0.	15719.	0.	-2688.44

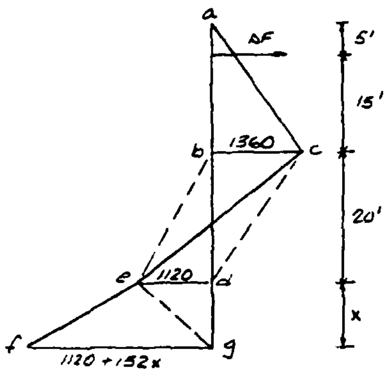
(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS
OF ELASTICITY IN PSI TIMES PILE MOMENT OF
INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES)

Verification of Problem "ANCH3" (Sheet 1 of 3)



Verification of Problem "ANCH3" (Sheet 2 of 3)

DESIGN BY FREE EARTH METHOD:
ASSUME PENETRATION BELOW EL -20



FORCE	PRESS DIAG	FACTORS	MOMENT ARM AF	MOMENT ABOUT AF
P1	acdb	1360(40)/2 = 27200	15	408000
P2	bde	-1120(20)/2 = -11200	(15+40/3)	-317333
P3	deg	-1120(x)/2 = -560x	(35+x/3)	$-19600x - 186.67x^2$
P4	egf	$-(1120+152x)(x)/2 = -560x - 76x^2$	(35+2x/3)	$-19600x - 3033.33x^2 - 25.33x^3$

$\Sigma F_H = 0 = \Sigma P = 16000 - 1120x - 76x^2 - AF = 0$

$\Sigma M_{AF} = 0 = 90667 - 39200x - 3220x^2 - 25.33x^3 = 0$

FOR $\Sigma M_{AF} = 0$, $x = 1.984'$ > 0 OK, PEN > 20'

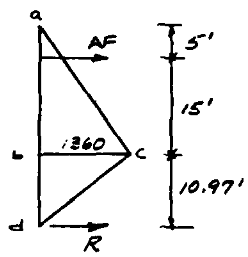
PENETRATION = 21.98' (PROGRAM 21.98')

FROM $\Sigma F_H = 0$, AF = 13478# (PROGRAM 13484#)

Verification of Problem "ANCH3" (Sheet 3 of 3)

DESIGN BY EQUIVALENT BEAM METHOD:

ASSUME POINT OF INFLECTION AT POINT d (FIGURE SHEET 1 OF)



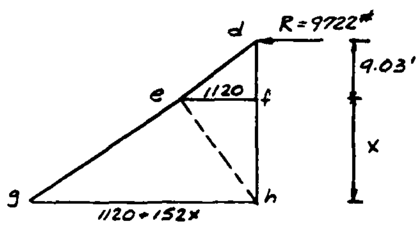
$$\Sigma M_R = 0 = AF\,(25.97) - 1360\,(20/2)(10.97 + 20/3) - 1360(10.97/2)(2/3)(10.97)$$

$AF = 11336^{\#}$ (PROGRAM $11336^{\#}$)

$$\Sigma M_{AF} = 0 = 1360\,(20/2)(40/3 - 5) + 1360\,(10.97/2)(15 + 10.97/3) - R(25.97)$$

$R = 9722^{\#}$

PENETRATION BELOW d



$$\Sigma M_h = 0 = R\,(9.03 + x) - 1120(9.03/2)(9.03/3 + x) - 1120\,(x/2)(2x/3) - (1120 + 152x)(x/2)(x/3)$$

or $72587 + 4664x - 560x^2 - 25.33x^3 = 0$

$x = 12.21'$

PENETRATION = $20 + x$ = $32.21'$ (PROGRAM $32.2'$)

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Dawkins, William P
User's guide: Computer program for design and analysis of sheet pile walls by classical methods (CSHTWAL); Report 1: Computational processes / by William P. Dawkins, Department of Civil Engineering, Oklahoma State University, Stillwater, Okla. (U.S. Army Engineer Waterways Experiment Station) ; prepared for Office, Chief of Engineers, U.S. Army, under Contract No. DACW39-79-M-1229 -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, 1981.
49 [157] p. : ill. 27 cm. -- (Instruction report / U.S. Army Engineer Waterways Experiment Station ; K-81-2, Report 1)
Cover title.
"February 1981."
References: p. 49.
1. Computer-Aided Structural Engineering Project. 2. Computer programs. 3. CSHTWAL (Computer program). 4. Retaining walls. 5. Safety factor. 6. Sheet piles. I. United States. Army Engineer Waterways Experiment Station. Automatic Data Processing Center. II. Oklahoma, State University, Stillwater.

Dawkins, William P
User's guide: Computer program for design and analysis...
1981. (Card 2)

III. United States. Army. Corps of Engineers. Office of the Chief of Engineers. IV. Title: V. Series: Instruction report (United States. Army Engineer Waterways Experiment Station) ; K-81-2, Report 1.
TA7.W34i no.K-81-2 Report 1

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981

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